SOCIETY OF ENGINEERS.

ESTABLISHED MAY 1854.

Journal and

TRANSACTIONS FOR 1890,

AND

GENERAL INDEX, 1861 TO 1890.

EDITED BY

G. A. PRYCE CUXSON,

SECRETARY.

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The Society does not hold itself responsible for the opinions expressed in this volume.

PREMIUMS FOR 1890.

AT a Meeting of the Society, held on the 2nd February, 1891 the following Premiums of Books were awarded, viz.:—

The President's Premium to:

W. H. BROTHERS, Assoc. M. Inst. C.E., for his paper on "Weighing Machinery and Automatic Apparatus in connection therewith."

The Bessemer Premium to:

R. H. TWEDDELL, Assoc. M. Inst. C.E., for his paper on "The Application of Water Pressure to Machine Tools and Appliances."

A Society's Premium to each of the following gentlemen:

To PERCY GRIFFITH, Assoc. M. Inst. C.E., for his paper on "The Treatment and Utilisation of Exhaust Steam."

To W. SANTO CRIMP, Assoc. M. Inst. C.E., for his paper on "Sewer Ventilation."

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SOCIETY OF ENGINEERS.

ESTABLISHED MAY 1854.

COUNCIL AND OFFICERS FOR 1890.

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OFFICES:
17, VICTORIA STREET, WESTMINSTER, S.W.

PLACE OF MEETING:
THE TOWN HALL, WESTMINSTER, S.W.

1891.

TRANSACTIONS, &c.

February 3rd, 1890.

INAUGURAL ADDRESS

BY

HENRY ADAMS, M. Inst. C.E., Etc.

President.

In assuming the duties and responsibilities of this chair, I desire in the first place to thank you for the great honour you have conferred upon me, and to express the hope that, with the assistance of my colleagues upon the Council, I may be enabled to discharge the functions of President with advantage to the Society.

As there is no special Annual Report presented by the Council to the Members, the Presidential Address forms a fitting place to give a brief record of the work of the Society during the year.

Founded in May 1854, by some former students of the Putney Civil Engineering College, its career has been marked by a more or less continuous progress to the present time, and the roll of membership now stands as follows:—

Honorary Members	18
Members	287
Associates	112
Total	417

During the year, twenty-one new members and eighteen new associates have been admitted, while seventeen members and twelve associates have been removed from the roll by death, resignation, or otherwise.

Among the deaths, we have to record those of our Honorary Member, Dr. John Percy, F.R.S., whose knowledge of metallurgy was of world-wide repute; Mr. Robert Paulson Spice, a Past President and warm friend of the Society; and Mr. W.

Stroudley, the Locomotive Superintendent of the London, Brighton and South Coast Railway, one of our ordinary members.

The list of honorary members has been increased by the election of Lord Armstrong in place of Dr. Percy, and the addition of Earl Granville, Lord Brassey, Sir William Thomson, Dr. William Anderson, and Mr. Benjamin Baker.

In order that the position of the Society may be maintained, it is essential that all its members should exert their influence to make its advantages known, and to induce any of their friends to join who may be eligible under one or other of its classifications. There must be progression or retrogression, and each member should feel an individual responsibility in securing the former and preventing the latter.

The papers read before the Society during the past year have been both practical and varied, and that they have been considered valuable is evinced by the award of premiums which you have just witnessed. The Council will always be happy to receive suggestions from members with regard to papers and subjects for discussion; no class of engineering is excluded so long as the subject is treated in a manner likely to prove useful to the Society.

The first paper which followed the able address of our Past President, Mr. Baillie, was one by Mr. G. R. Strachan, on "The Construction and Repair of Roads." The paper was confined to town roads under heavy traffic, and the cost given applied to the metropolis. The standard adopted was "tons per yard of width per 16 hours." The true principle of road construction was stated to be to make the foundation the real road and the material thereon a wearing surface only; this secured the greatest economy. Particulars were given of the actual construction adopted in various cases, together with the first cost and cost of maintenance, and the author reviewed the respective merits and demerits of macadam, granite pitching, asphalte, and wood.

The next paper, by Mr. G. M. Lawford, on "Fireproof Floors," was capitally illustrated, and detailed descriptions were given of various types of construction as instances of modern practice. The conclusion arrived at was, that although the floors described were capable of giving great resistance to fire, retarding its action by confinement, and in this way giving greater chances of extinction, a brick arch was the only absolutely "fire-proof" floor, and that it would be more correct to describe the others as "fire-resisting."

Following this was a paper by Mr. Perry F. Nursey, Past President, on "Recent Developments in High Explosives."

He described how the explosive had to be selected according to the work required to be done, showing that the explosion in some was intensely rapid and smashed the rock within a limited area, whilst in others the rate of explosion was more retarded, so that they rent and fissured the ground over a large area, to the manifest advantage of the miner.

Mr. Henry Faija, who has been recently elected a member of Council, read a paper upon the "Forced Percolation of Water through Concrete," detailing particulars of experiments he had carried out in continuation of his paper read before the Society in the previous year "On the Effect of Sea Water on Portland Cement." In all, nearly one hundred experiments were carried out, the briquettes being, in all cases, gauged in the proportion of three parts of standard sand to one part of cement. The primary matter to ascertain was the comparative tensile strength of the briquettes treated in different ways with both fresh and salt water. The average time during which they remained sufficiently porous to allow of the filtration of water was 88 days, and the average amount of water which filtered through each briquette was 271 ounces. Chemical analysis accompanied the experiments, and the result arrived at was that, with a good and properly used cement, no deterioration took place through the forced percolation of water, whether sea or fresh.

Mr. J. H. Cunningham, another member of the Council, read a very useful paper upon "Pin-connected *v.* Riveted Bridges." He took for illustration, the designs for a bridge to carry a railway across the Mary River in Queensland, which he had worked out in detail, one design having pin-connected trusses with long panels such as are common in America, and the other lattice bar trusses with all the joints riveted. After comparing the advantages and disadvantages, he considered that for moderate spans up to 500 feet, the pin-connected bridges would be more economical and more easily erected than riveted ones, and American experience confirmed these conclusions. He thought English engineers were fully alive to the importance of adopting improvements in bridge building, and suggested that progress was more likely to be made by greater care in designing, and more use of machine tools in constructing, than by the invention of new types of trusses.

"Modern Gas Engine Practice," by Mr. S. Griffin, was the next paper presented to the Society. The principles and the method of construction adopted in each of the more important types were described and illustrated, and a few of the directions were indicated in which the development of the gas engine

may be expected to extend, improvement being looked for in matters of detail rather than in the discovery of any new principle.

The last paper of the session was another by our good friend and Past-President Mr. Perry F. Nursey, on "Fox's System of Solid Pressed Steel Wagon Frames." These were now superseding the old fashioned wood and iron frames, and effected a saving in weight of 20 per cent. per wagon; another advantage was that whereas wood frames were valueless at the end of the wagon's life, the value of the steel frames as scrap, was always that of pig iron. Other advantages were—fewness of parts, interchangeability, duplication of parts, and longer life in rolling stock on account of the elasticity of the frames. Models of various underframes, samples of the steel, and a large collection of diagrams, rendered the paper very complete and interesting.

A popular and instructive feature of the Society's work is found in the visits which are paid to places of engineering interest during the summer. The social element of these meetings is a welcome addition to the laborious life of an engineer, and the recent visits have more than sustained the reputation of their predecessors.

On the 27th June a visit was paid to the East London Waterworks at Lea Bridge, Walthamstow, and Waltham Abbey, where the members and their friends were received and entertained at luncheon by the Engineer of the Waterworks, Mr. W. B. Bryan, M. Inst. C.E., and conducted by him over the abovementioned establishments. The East London Waterworks Company was founded in 1808, by the amalgamation of the Shadwell Waterworks Company, dating from 1669, and the West Ham Waterworks Company, dating from 1747, and large reservoirs were constructed at Old Ford. The intakes have since been carried higher up the Lea to Ponders End, and the new reservoirs at Walthamstow, covering 236 acres, have an available capacity of 610 million imperial gallons. The Company has also sunk several wells into the chalk, and has an auxiliary supply from the Thames above Sunbury Lock. The magnitude of the undertaking is shown by the fact that about 1,235,000 inhabitants receive their supply through its pipes. It is interesting to note that the pair of engines called "The Twins," built by Messrs. Boulton and Watt, at the Old Ford station, are still, after 80 years' service, in fair working order, and work with a fair economy.

The next visit made by the Society was on the 30th July, to the Outfall Sewage Precipitation Works now in progress at Crossness, where the party was entertained at luncheon by the

Contractor, Mr. W. Webster, and afterwards conducted over the works by Mr. F. E. Houghton (Resident Engineer), and Mr. Webster. These works form the outfall into the River Thames for the whole of the sewage of the Metropolis south of the river. The sewage reaches Crossness by an 11 feet 6-inch barrel sewer at a deep level, and is there pumped into existing reservoirs capable of holding 4,000,000 cubic feet of sewage, which is stored for about 8 hours per tide, and discharged at high water. The Precipitation Works now in progress, the contract for which was let to Mr. Webster for 258,166*l.*, comprise the alteration of the old reservoirs and the addition of new ones, which, when completed, will provide for 12,000,000 cubic feet of effluent per day. The sewage, after being treated with lime water and iron water, will be separated by precipitation into effluent and sludge; the effluent will run off into the river almost continuously, and the sludge will be pumped into sludge ships for conveyance and discharge into the German Ocean. The works are designed with a view to the treatment of the sewage for a future population of 2,400,000 persons, within the area of so much of London as lies south of the Thames.

On the 1st October, a visit was paid to the Central Station of the London Electric Supply Corporation at Deptford, where the members were received and entertained at luncheon by the directors, and were afterwards conducted over the works by Mr. Sebastian Ziani de Ferranti, the engineer to the Corporation, who has invented, designed, and laid out the whole of the scheme. These premises promise to be one of the most remarkable industrial establishments of the metropolis. The site occupies about 4 acres on the riverside. The boiler-house is 195 feet long by 70 feet broad and nearly 100 feet high, constructed to contain boilers of 65,000 horse-power, arranged on two floors with a coal store above. There are two engine-houses, each 195 feet in length, 66 feet in breadth, and about 85 feet high. In the first engine-house, a pair of Corliss engines of 3000 horse-power will be erected, to actuate two Ferranti dynamos, each capable of supplying a current for 25,000 lights. In the second engine-house will be placed the large engines and dynamos, of which there will be two sets; each dynamo 40 feet high and 500 tons weight, worked by a pair of vertical Corliss engines of 10,000 horse-power. The electric current will be alternating, generated at high tension, conveyed by cables to the distributing stations, and there converted by means of transformers to a lower tension, and finally converted to a low tension on the premises of each consumer, where the consumption will be registered by meter. The

directors have arranged for the eventual supply of two million lights.

On the same day the members of the Society visited the Foreign Cattle Market, Deptford, and were conducted over the premises by the Superintendent, Mr. George Philcox.

The Market was provided by the Corporation of the City of London under the Contagious Diseases (Animals) Act of 1869, for the slaughter and sale of animals from scheduled countries, i.e. from countries where disease was known or suspected to exist. It cost in the first instance 255,000*l*., and was opened for public use on the 1st January, 1872.

The Market was constructed on the site of H.M. Deptford Dockyard, and occupied a space of about 25 acres, which has since been increased to 30 acres, with river frontage of upwards of 1000 feet. The old shipbuilding slips and docks were filled up and lairage for cattle and sheep provided on their site. The warehouses and other buildings were converted into slaughter-houses and other premises necessary for the purpose of carrying on the business of a large slaughtering establishment, as no animal is allowed to leave the market alive. For the purpose of landing animals consigned to the market, three substantial jetties were constructed, extending into the river 165 feet. Vessels ranging from 400 to 4000 gross tonnage, land cattle at these jetties; Continental steamers can berth alongside at all states of the tide, and Atlantic steamers at about half-flood tide. Animals are landed immediately the vessel arrives, both by day and night. Covered lairage is provided for about 5000 head of cattle and 23,000 sheep, and there are about sixty-two separate slaughterhouses. A refrigerating machine has lately been added to the market, having chill rooms attached, for the purpose of cooling fresh meat in hot weather. About 10½ million animals have been landed and slaughtered at Deptford since the opening of the market.

This brief review of the principal work of the Society during the past year is sufficient to show that its membership is worth having, and it is satisfactory to be able to add that its financial position is an improving one, the revenue being in excess of the expenditure.

I now turn to other matters which may be of interest, and which extend beyond the limits of our own Society.

Technical Education.

Having been intimately connected with Technical Education for nearly a quarter of a century, it may be expected that I should make a few remarks from my own standpoint upon the position of that much debated subject in relation to engineering. I have the less hesitation in doing this as the Council of the Society of Engineers has at various times given particular attention to the subject with the view of increasing the usefulness of the Society to the junior members. Fifteen years ago the then Secretary applied to me for information upon technical examinations, to enable the Council to consider the feasibility of adopting some form of public examination for young engineers; and it is seven years since they arranged for the delivery of several courses of lectures upon practical subjects, of which I had the honour of delivering the first series. Quite recently they have discussed the question of providing special papers for students, or lectures of an educational character, upon various branches of engineering work; and, although the matter is postponed for a time, they hope ultimately to carry some such arrangement into effect.

Technical Education in its present significance dates from the foundation of the Conservatoire des Arts et Métiers in Paris in 1775, and the various Ecoles des Arts et Métiers arising out of it, particularly the Ecole Centrale in 1829, yet it was not until after the Great Exhibition of 1851 that Englishmen as a body paid any attention to the subject. While that Exhibition demonstrated the paramount excellence of the English nation in all constructive branches where utility was concerned, as well in solidity of workmanship as in mechanical accuracy, it showed how far they were behind many other nations, notably the French, in the application of taste and artistic skill to their manufactures. Unfortunately, we only learnt a part of the lesson which was displayed before us; efforts were made in all directions to improve our art productions, but no corresponding effort was made to retain the supremacy of our machinery; and, consequently, in the Paris Exhibition of 1855, and still more in our own of 1862, we found French, German, and American machinery able to compete on equal terms with English machinery, and in some points to surpass it. The Paris Exhibition, just closed, is perhaps too recent to permit of a deliberate judgment being formed upon it; every one may have his opinion, but a verdict of historical value has hardly been pronounced. Whether, in the undoubted progress we have made during the last thirty years, we have recovered our supremacy, is open to

question, whether we are going about it the right way is even a disputed point, and a brief review of our system of education will not be out of place.

In 1835 Mr. William Ewart, M.P. for Liverpool, induced the House of Commons to appoint a Select Committee to inquire into the best means of extending a knowledge of the arts and the principles of design amongst the people. Arising out of this a School of Design was opened at Somerset House in 1838, and in 1840 the Government decided to assist in the establishment of similar schools in manufacturing districts. In the Speech from the Throne in 1852, Her Majesty stated that "The advancement of the fine arts and of practical science will be readily recognised by you as worthy the attention of a great and enlightened nation. I have directed that a comprehensive scheme shall be laid before you having in view the promotion of these objects." The passing of "The Literary and Scientific Institution Act" in 1854, under which our own Society was formed, and "The Public Libraries Act" in 1885, gave an impetus to local effort in the establishment of evening classes, whereby persons engaged in other pursuits during the day, could if they chose, attend classes or lectures in various subjects of science, art, and literature in the evening. It was not until 1864, however, that the Department of Science and Art was incorporated by Royal Charter, and the steady increase in the numbers of the students attending the classes under its supervision and control, show that its popularity is unimpaired, notwithstanding the adverse criticism it has received at various times. At the present moment there are about 200,000 students in the Science division, and a much larger number in the Art division, facts which show that, to some extent at least, the English nation recognises the importance of applying the principles of art and science to manufacturing production; and if the instruction be given in the right way, its influence cannot fail to be in every way beneficial to the national industries. I say advisedly, if the instruction be given in the right way, because it is the opinion of many men at the present day that the sound practical judgment which formerly distinguished the English engineers is fast being educated out of the race, and that as book knowledge increases, common sense diminishes. This is a very serious matter, and one deserving the most assiduous attention from technical instructors. Education in its true sense is the development of the power of observation and the formation of sound judgment, and any mere cramming of facts and formulæ tends to kill all that is noble and useful in the intellect of the engineering aspirant.

It may be objected that the Science and Art Department does

not provide for the education of engineers properly so called, that it caters for workmen only. Entering the workshops at a very early age, it is mainly to evening classes that I owe my knowledge of scientific principles, and this must be so in many other cases among members of the engineering profession, as the great bulk of the work in technical and scientific education is done at the evening classes carried on by the thousands of science schools and institutes throughout the country; and although a large proportion of the students is drawn from the artizan class, there are many middle-class students only too glad to avail themselves of the opportunities therein offered. The general result has been a dissemination of scientific knowledge, which has left its mark upon the work produced during the last decade, and which bids fair to produce still higher results in the future.

It cannot be denied that even some of the Whitworth Scholars, who are the cream of the Science and Art Department, are lacking as engineers, but a far greater number have proved themselves to be thoroughly capable men, and many of the names now quoted as leading authorities on mechanical matters, may be found in the earlier lists of students under the Department. Dating from the time when Dr. Anderson, of Woolwich, was appointed Examiner in Applied Mechanics, and Professor Unwin in Machine Construction, the Science and Art Department has been no mean factor in the advancement of mechanical engineering. The establishment of the Honours Stage has tended to raise and maintain the standard of technical knowledge throughout the country, and although there are no strictly civil engineering subjects, the Honours Stage of Building Construction covers much of the ground that a civil engineer is expected to be conversant with.

The City and Guilds of London Institute for the Advancement of Technical Education, founded classes throughout the kingdom in 1879, upon the lines of those in connection with the Science and Art Department, but with more direct reference to actual trades, and the principles underlying them individually. In the Session 1888–9, there were 11,874 students attending in 520 classes at 231 centres; of these 5748 sat for the annual examination, and 2939 passed. At the Central Institution, erected at a cost of 100,000*l.*, and opened on the 25th June 1884, instruction of a higher and more advanced character is given, where it is anticipated will be trained the main body of technical teachers, who are expected to carry from it a knowledge of the theory and the practice of various crafts and industries.

A City Polytechnic is in course of formation by the union of the City of London College and the Birkbeck Institution with

the proposed Northampton Institute, which will be erected in Clerkenwell. They will retain their own executive councils acting under a joint governing body, and an annual sum of 5330*l*. is to be set aside by the Charity Commissioners towards their maintenance, beside a present grant. It may not be generally known that the City of London College, founded in 1848, has a staff of forty Professors and Lecturers, giving instruction in upwards of fifty different subjects, and that the attendances of students for the Session of seven to nine months average 70,000, representing say 3000 individual students. The Engineering Department, for which I am mainly responsible, was established in 1869, and is attended by a weekly average of 250 students. The instruction is by means of evening lectures illustrated by diagrams, working drawings, and models, with occasional visits to works. It is intended as an accompaniment to, and not a substitute for, the office or workshop, as those who attend are mostly beyond the age when they can afford to devote their whole time to study.

Many of our semi-public schools are now providing laboratories and workshops, in which those lads who have a taste for technical pursuits may get their first insight into the use of tools, while still pursuing their preliminary studies. In no case can it be a disadvantage to them, and it is a positive boon to those whose physical energy is unequal to the labour of joining in the rough-and-tumble school sports, while it may be the means of rescuing some embryo Stephensons, Armstrongs, and Whitworths from the drudgery of a merely commercial life. Sir Edmund Currie has recently endeavoured to formulate a system of education which shall better adapt the sons of engineers for a professional career, and he is now putting his theory into practice. My own idea is that to complete the school education of a young engineer, we want a sort of higher Slöjd system, to develop the constructive faculties and to produce a positive manual dexterity, at the same time that the intellect is engaged upon maintaining the action in the most direct course to reach some definite end in view. This is partially done in the laboratories attached to the engineering departments of some of the colleges, and in the admirable school of practical engineering at the Crystal Palace, of which Mr. W. J. Wilson, Jun., one of our Vice-Presidents, is the life and soul; and there is little doubt that as experience in this form of tuition matures, very valuable results will accrue. Had the universities of Oxford and Cambridge continued to foster the aim of the earlier founders of the colleges, which was exclusively the preservation of the knowledge extant in their time and its development by the association and mutual help of men devoted to a common

object, engineering would long ago have been classed as one of the learned professions, and opportunities for acquiring a knowledge of it would have formed part of the ordinary curriculum of a liberal education, specialised in its higher branches, as in the case of medicine, law, and divinity. Until recent years, mathematics, with elementary mechanics as a subdivision, was the only directly useful part of a college education so far as engineers were concerned, and chiefly to Professors Rankine, Unwin, and Kennedy, the credit is due of showing that there is work to be done in establishing the principles of engineering as a practical science which is not unworthy of the highest educational powers in the land. In the proposal to form a new university for London, under the title of the Albert University, to incorporate the examining powers of the present University of London, and the teaching functions of University and King's Colleges, a suitable opportunity offers for engineers to press the claims of their profession as regards facilities for advanced instruction and original research, as well as for the creation of a degree which shall confer a recognised status upon the recipients.

But we may well ask ourselves—What is the use of all this technical education in improving our national productions, if the coercion practised by some of the Trades Unions is to continue? By their interference with the freedom of contract, an articifial rate of wage is produced by which we are placed at a disadvantage in competition with other countries, with the result that our output is restricted and the wage fund reduced, so that although a few men may receive higher wages, a much larger proportion must ultimately receive either less than before or none at all. The tyranny of one class over another, whether higher or lower in the social scale, is fatal to the progress of both. Strikes to improve the position of the workmen of each trade in turn, at the expense of the rest of the community, would, if carried to extremes, put the population in the position of the islanders in the old story, who "obtained a scanty and precarious livelihood by taking in each other's washing." As pointed out by an able writer in the *Standard*, the moment a general strike is brought about, the strikers are bound to realise the fact that each, though doubtless a labourer in one trade, is an employer in many others; and that the striker in one capacity is, in fact, levelling a blow against himself in another.

Some system of profit-sharing between employer and employed would seem to offer the best solution to the termination of this internecine struggle, and if the Trades Unions have really the benefit of the working man at heart, and not the

aggrandisement of a few at the expense of the many, they will do well to devote their energies to finding a *modus vivendi* upon this basis.

I cannot close this part of my address better than by quoting a paragraph from one of Professor Huxley's speeches. "The terrible battle of competition between the different nations of the world is no transitory phenomenon, and does not depend upon this or that fluctuation of the market, or upon any condition that is likely to pass away. It is the inevitable result of that which is at the bottom of all the great movements of history—the struggle for existence. With a population far in excess of that which we can feed, we are saved from a catastrophe solely by our possession of a fair share of the markets of the world ; and our sole chance of succeeding in a competition which must constantly become more and more severe, is that our people shall not only have the knowledge and skill which are required, but that they shall have the will and the energy and the honesty without which neither knowledge nor skill can be of any permanent avail."

Our Colonies.

It is patent to all that England is not large enough for the number of engineers produced within its shores, and that a wider field of enterprise is necessary to develop their skill, and even to permit them to earn a living by their profession.

If we may judge from the addresses given in the list of members of the Institution of Civil Engineers, the percentage distribution of the different classes is as follows :—

	Home.	Foreign and Colonial.
Members	70·4	.. 29·6
Associate Members	64·5	.. 35·5
Students	80·9	.. 19·1

Taking the total average, allowing for the varying numbers in each division, we have as nearly as possible 30 per cent. practising abroad, either from choice or necessity, and the recent address of the President of the Institution of Civil Engineers, Sir John Coode, K.C.M.G., upon the "British Colonies as fields for the Employment of the Civil Engineer," was therefore peculiarly appropriate to the circumstances.

Our own Society, which is perhaps rather less cosmopolitan, gives :—

	Home.	Foreign and Colonial.
Members	80·28	.. 19·72
Associates	89·72	.. 10·28

A more intimate knowledge of individuals would show that even a larger percentage in both lists practise beyond their native shores, for many retain their home address when they accept a three years' engagement abroad; and no one thinks of publishing his postal address when he makes a professional visit of a few weeks or months beyond "the silver streak."

In this connection engineers may well give a moment's thought to the subject of Imperial Federation. As the foreman in each department of a successful engineering establishment is the best judge of how to carry out most efficiently, with the means at his command, the work executed in that department, while only the general manager or head office is competent to deal with subjects affecting the relationship of the various departments and to keep the establishment *en rapport* with the outside world, so it would appear that the mother country and the colonies must be the gainers by a system of federation which shall leave each country or colony to conduct its own internal affairs, while they contribute representatives to share as one body in the deliberations upon questions of Imperial policy. Some minds are adapted for executive and administrative work, others have a far-reaching capacity, which better fits them for diplomatic and Imperial service; and the subdivision of labour in this way should produce as good a result in the political world as it does in the industrial world.

Imperial Federation, by uniting in one bond of self-interest and social unity many distant parts of the world, would facilitate the work of the engineer, and this work would, by reaction, do more than anything else to ensure the stability and enhance the prosperity of the British Empire.

It has been said that there are three classes of persons whose co-operation is essential to the work of successful and permanent colonisation; these are—the soldier, the policeman, and the engineer. The first represents the safety from external aggression, the second the maintenance of law and order, the third the settlement of the land and the establishment of arts and manufactures. In every quarter of the globe new fields of engineering enterprise are being opened up, which promise results of which we can hardly form an adequate conception, and by the work of engineers the world becomes more and more one vast community.

No imagination can be so commonplace as not to be stirred to enthusiasm by a contemplation of the enormous possibilities of practical science. In new countries, where there are no vested interests to disturb, and no sunk capital to regret, the engineer is able to utilise to the fullest extent the heritage of experience which has been left him by other generations and

by workers in allied fields of industry, and if the Colonies do not succeed, it will not be from the lack of natural advantages.

Sir John Coode pointed out that the keynote of the Colonial question was best represented by the word "transport;" where there was trade there would of necessity be a demand for the means of transport, and where there was a demand for the means of transport there would be found a need for the work of the civil engineer. Whilst the population had increased by a little less than 10 per cent. between 1870 and 1880, the increase in transport within the same period had been fully 53 per cent. The connection was obvious between transport and the several engineering works comprehended under the construction of railways, tramways, roads, canals, harbours, docks, steamships, locomotives, bridges, viaducts, tunnels, &c.

Besides these, there are works more intimately connected with the settlement of the land, such as irrigation, water supply, lighting, sewage, and drainage works. The necessity for irrigation works depends upon conditions of soil and climate which are unknown in this country, but in many parts of the Colonies the prosperity of the neighbourhood is solely dependent upon efficient irrigation. In those parts the soil and the sunshine are present, and the lack of rainfall has to be supplemented by artificial means. At the present time two large areas adjacent to the River Murray, in the Colonies of Victoria and South Australia, are being laid out for irrigation under very favourable circumstances. Similar places occur in Spain, along the coasts of the Mediterranean, in Florida, California, and elsewhere, only waiting for the advent of an enterprising company.

Sir John Coode gave so complete an account of the work now going on in Greater Britain, that I could hardly describe it without being guilty of plagiarism; and I would only further remark, in this connection, upon the bond of sympathy which exists between the members of our Society and their professional brethren in the Australian and other Colonies.

Marine Engineering and Shipbuilding.

The consideration of transport directs attention to the enormous strides which are being made in ocean navigation. According to 'Lloyd's Register' of 1888–89, there are 6442 British ships, with an aggregate tonnage of 7,076,494, the numbers being divided as follows:—Iron steamers, 2905; steel steamers, 496; iron sailing vessels, 1485; steel sailing vessels, 88; wood vessels, 1468—showing how wood has been superseded by metal since the first iron steamer, the *Sirius*, was registered in 1837. The use of metal developed slowly, owing to

the popular bias in favour of "the wooden walls of Old England," and a separate classification of iron vessels was not adopted until 1854. Although steam ships predominate, we can hardly say that the days of sailing ships have quite departed, since Messrs. Bordes & Son, of Paris and Bordeaux, recently gave the order for a five-masted steel sailing ship, to carry 6000 tons dead weight; and several others of large size are building.

The past year has seen the enormous output of 1,270,000 tons of British shipping, exceeding even that of 1883, which was the largest previously known, and being double that of some of the intervening years. This unexampled prosperity has been accruing from the year 1886, and there are at present no signs of its diminution. Whether all these vessels can be employed at a remunerative figure depends upon the general prospects of trade; but, fortunately for engineers, if there is any pinch, there is work to be done for some time yet in converting the old-fashioned boats to the more modern types. For instance, the s.s. *Argus*, recently converted from a paddle steamer to a twin-screw boat with triple expansion engines, has shown extraordinary economy; as a paddle-boat her sea-going speed was 10½ knots on a consumption of 26 tons per day, now her sea-going speed is 11 knots on a consumption of 8 tons per day.

The highest examples of skill in mechanical engineering are reached in the modern marine engine. The great improvements that have taken place during the last few years would lead one to suppose that the climax must already be reached, were it not that better results are chronicled daily. Fifty years ago 6 to 9 knots per hour was the range between ordinary and extraordinary performances; now we have 15 to 20 knots for the same classes of steamers, and this upon a smaller consumption of fuel. The "greyhounds of the Atlantic," instead of burning 12 lb. coal per I.H.P. per hour with a speed of 8 knots, as prophesied by Dr. Lardner in 1835, now accomplish double that speed on a fuel consumption of about one-seventh.

The greatest problem with marine engineers has always been to get the maximum power with the minimum weight of machinery. We are now able to get 20 I.H.P. per ton weight of engines and boilers. On the four hours' trial of the *Elizabeta*, built at Elswick and engined by Mr. F. C. Marshall, the speed of the vessel was 18 knots, with a displacement of 1263 tons, and the approximate mean I.H.P. 5000, while the total weight of machinery and water was under 250 tons. In such examples as this the weight of the machinery has, by careful designing,

been reduced to a minimum consistent with the strength of the material.

The compound engine is no new invention; Jonathan Hornblower's patent for the use of two cylinders in which to effect continuous expansion is over a century old (13th July, 1781), but its birth was premature and it was still-born, owing to the want of high-pressure steam to give it life. As the use of higher pressures became general, many inventors entered the field, but it was not until about twenty years ago that compound engines were established as the proper type for the motive power of steamships. Still more recently we have made the change to triple- and quadruple-compound. It is simply a question of boiler pressure, the economical expansion in any one cylinder being limited to about $2\frac{1}{2}$ times, and the final pressure being brought down to that with which the condenser is capable of dealing. The first result of compounding was to increase the weight of the engines, but the increase of pressure enables the steam to be used so much more efficiently that the ultimate result is a saving of the total weight. The reduction of the fuel per I.H.P. is a cumulative advantage; there is the actual saving on its cost, and by allowing the bunker space to be curtailed the cargo-carrying and freight-earning capacity is correspondingly increased. The next step towards a general improvement would appear to be the economical application of a moderate forced draught direct to each furnace without using a closed stoke-hold. In a test of two steamers of the City Line under practically equal conditions, except that the boilers of one had Howden's system of forced draught and the other boilers worked by natural draught, the saving of cost upon a voyage to Calcutta and back via the Suez Canal was 430 tons, or $22\frac{1}{2}$ per cent. in favour of forced draught. The White Star, Inman, and other lines are adopting forced draught, and it is now possible to build a ship capable of carrying 6000 tons, to steam an average of 10 knots per hour at sea, upon a consumption of 30 tons of coal per day. The ordinary practice is for compound engines to develop 9 to 12 I.H.P. per square foot of fire-grate under natural draught, and 15 to 18 I.H.P. under a pressure of 1 inch or $1\frac{1}{4}$ inch of water, rising to, say, 21 I.H.P. in triple compounds.

Forced draught seems to be looked upon as perfectly legitimate, but there is little difference in the wear and tear of a boiler between forced draught and hard firing with natural draught. If forced draught is to be adopted generally, it is open to question whether some alteration in the construction of marine boilers is not desirable.

The possible improvements in efficiency are no longer among

the units, it has come to a question of decimal figures only; hence the importance of minute accuracy in the detailed trials which now occasionally take place, such as that by Professor Kennedy and others on the *Meteor*. Similar trials in a college laboratory are principally useful for educating a sufficient number of competent assistants, the engines themselves being too small for the results to be comparable with outside practice. Owing to the exigencies of trade and commerce, it is exceedingly difficult to get owners to permit exhaustive trials to be made on a large scale, but the Admiralty might well give facilities for these investigations; although it could not be done without some expense to the country, the cost would be trifling compared with the value of the information which might be elicited.

Typical of the "great things in steamships" may be mentioned the *Teutonic*, built by Messrs. Harland and Wolff, Belfast, for the White Star Line:—Length, 582 feet; breadth, 57 feet 6 inches; depth, 39 feet; gross tonnage, nearly 10,000 tons; carrying 300 saloon, 150 second-class, and 750 steerage passengers. The special feature of this vessel is that the plans were submitted to and approved by the Admiralty as were also those of the *Majestic*, a sister ship. They are so arranged that twelve guns can be mounted on each ship forty-eight hours after arrival in port, and it is believed that with their attributes of twin screws, high speed, great strength, and coal endurance, these two steamers will play an important part in realising the hope of seeing the Royal Navy and Merchant Service bound together in one common scheme for the protection of our commerce and the defence of the Queen's dominions.

It is estimated that Great Britain has built and now owns upwards of eight million tons of shipping, or three-fourths of the whole mercantile tonnage of the world; and to safeguard this it is absolutely necessary to maintain a Royal Navy that shall be able to command the respect of other nations, and shall ensure peace by being prepared for war.

Preparation has been made for the immediate future by the Government having decided to add in all seventy new ships to the Royal Navy, with a total tonnage of 318,000 tons, of which thirty-eight, at a cost of 11½ millions, are to be built in the Royal dockyards, and the remaining thirty-two, at a cost of 10 millions, are to be built by private contract. These estimates were based upon the current rates for wages and material at the beginning of last year, and the rise that has taken place since may possibly necessitate some reconsideration.

So far, contracts have been let for four of the eight first-class

battle ships, three of the nine first-class cruisers, seventeen of the twenty-nine cruisers of the *Medea* type; and in the Government yards there have been commenced some nine or ten of the various classes, principally of the larger types. The contracts have been very fairly distributed over the great shipbuilding and marine engineering centres, and have given general satisfaction to those concerned. It is assumed that the total cost of 21½ millions will be spread over a period of seven years. Previously all amounts voted had to be spent within the year, or they were lost to the department; but the principle of basing manufacturing estimates upon a term of years must lead to a better return being obtained for the money.

Although England is insignificant on the map of the world, no other country can muster such a magnificent array of offensive and defensive force as we placed before the German Emperor at the naval review in August last; and we may well be proud of our first line of defence, notwithstanding the periodical epidemic of pessimism which attacks the nation. On that occasion there were present 112 British fighting ships of all ranks, with a total displacement of over 320,000 tons, and an I.H.P. of over 400,000. There is much that is unreal about the naval manœuvres as training the crews for active service, they are perhaps better entitled to be looked upon as annual tests of the capabilities of marine engineering; speed coupled with security from breakdowns, is what is expected after long intervals of rest. The speed on the measured mile is an ideal which is not attainable in practice; even the four, six, or twenty-four hours' run shows a result which cannot be maintained, but the immunity from accidents and the more than punctuality which characterise the ocean-liners of our large steamship companies, are certificates of skill which need no vellum. The time has surely arrived when the engineering staff on board ship should have a better recognised status, the Extra-First-Class Certificate of the Board of Trade is evidence of a high degree of scientific knowledge, which has, in most cases, had to be obtained under circumstances of peculiar difficulty; and yet the holders are not treated as they would be if they were in corresponding positions on land, or even on deck. The mechanical engineer has hitherto been looked upon as a mere workman; now, the complication of mechanism in all departments is necessitating the employment of educated men, and there is no longer a difference in the social standing of a civil as distinguished from a mechanical engineer.

Iron and Steel.

Since the revival of the shipbuilding trades, and the general activity promoted thereby, the supply of iron and steel has been quite unequal to the demand; but, apparently fearful that this prosperity may not continue, there is an evident indisposition on the part of capitalists to lay down plant to meet the increased demand; and consequently, the booking of orders for material goes by favour, and the execution of the orders, even then, is only to be looked upon as among the possibilities of the dim future.

The production of iron is giving place more and more every year to that of steel, and there seems a probability that in a few years we shall be unable to obtain wrought iron. The old classification, by which the amount of carbon determined the name and nature of the material, has had to be discarded, as some steel now contains less carbon than some iron, and the better definition of steel would seem to include "all those malleable forms of commercial iron containing iron and carbon produced from a state of fusion into a malleable ingot." The advances of recent years in marine engineering, although due principally to the use of high pressure steam, would not have been possible had not a material been introduced which was stronger than wrought iron. The use of steel for the various forgings about an engine, and particularly for the crank shafts, has lessened the weight of the parts, and has enabled the diameters of the journals to be reduced so as to minimise the losses by friction.

For boilers, the use of steel has permitted larger plates, with a corresponding reduction in the extent of the joints, saving first cost in riveting and caulking, reducing the cost of maintenance, and extending the ultimate life of the boiler. The increased strength of the material also adds to the economy of working, by giving thinner plates through which the heat has to be transmitted to generate steam. For other purposes steel has shown a want of stiffness that has hampered its use. The great defect of mild steel is that the elastic limit is so low compared with its ultimate tensile strength, that it has a very marked want of rigidity, and in the form of plates, when subject to rough usage, is for this reason more indented and knocked about than wrought iron of the same thickness. Although the wrought iron many be fractured sooner, it retains its shape better.

Experiments are now being made with a new steel containing nickel, which is said to be much more rigid, while the ultimate strength is increased, and none of the essential pro-

perties of mild steel are sacrificed. The theory of the inventors of the alloy is based upon M. Chernoff's view of the composition of steel—that it is composed of crystals of metallic iron cemented together by carbide of iron—and they hold that the nickel alloys with the carbide of iron to form a stronger cement, by causing the approximation of the temperatures of solidification of the crystals and cement, producing a more intimate interweaving of the elements, rendering the cohesion more powerful, and more completely filling the spaces between the crystals. Up to 1 per cent. of nickel the material can be welded, and stands punching very well.

One of the difficulties not yet overcome by mechanical engineers is the testing of large forgings, and especially the crank shafts of marine engines, for hidden flaws. From time to time serious accidents occur from defects that have escaped the Argus-eyed inspectors and the many persons who have handled and examined the pieces. These defects generally arise from a break in the continuity of the substance, more or less distant from the surface. Sometimes they can be detected by a hammer, but in a large forging this test is inadequate. It is well-known that a bar of soft iron becomes temporarily magnetic while it is held at such an inclination and direction as would be occupied by a magnetic dipping needle placed in the magnetic meridian, and it will in this position affect an ordinary compass needle when brought near it; but if the continuity of the bar be not perfect, it will act as separate magnets would do and show polarity at those points. Acting upon this fact, Mr. S. M. Saxby, R.N., some time ago suggested the use of the compass needle to detect hidden flaws, and experiments were made at the Royal Dockyards of Chatham and Sheerness, which appeared to establish the practical value of this test. It does not, however, seem to have been adopted, possibly from its extreme sensitiveness, leading to the rejection of material considered, by those interested, to be good enough. In smaller work the measurement of the uniformity of elongation under stress is a possible, but hardly a practicable test, and at present we have virtually only the sound of a blow by a hammer to guide us as to the homogeneity of any given piece.

In Mr. Walmisley's address to you two years ago, many admirable illustrations were given of the extended use of steel, and its use still continues in an increasing ratio. The Eiffel Tower is probably the last great structure we shall see in wrought iron; for the proposed tower in London the conditions of competition state that "the material preferred is steel."

Phosphorus, which has been the great drawback to the economical production of steel in the past, and has called for

the highest skill of the chemist to effect its removal, is apparently about to prove another blessing in disguise. According to Mr. J. W. Bennett, the iron-working districts are likely to receive immense impetus from the increase of our chemical knowledge; mountains of what was formerly thought of as mere slag, and looked upon as purely useless stuff, have been discovered to contain phosphorus in such quantities that millions of money may be extracted from it. Those who have followed the utilisation of waste products in the case of gas manufacture will be prepared to see a great reduction in the cost of iron and steel, if Mr. Bennett's views are well founded.

Another utilisation of a waste product from manufactured iron is that by which nails are made from tinned sheet-iron scrap. The scraps of tin are cut by dies into rectangular pieces, with a length of about three times their width, then fed from an automatic hopper between dies, where they are squeezed first to a square form like a nail and then headed. They are very light and rigid, capable of being driven into hard wood without buckling, and free from tendency to rust.

As "dirt" is only "matter in the wrong place," so there ought to be no such thing as waste products; the term by-products introduced by gas engineers is far more appropriate to the modern industries, and there are doubtless many "gold mines" nearer home than the Transvaal to be worked by the fortunate inventor who shall utilise what other men have thrown away.

Our Fuel Supply.

The supremacy of England rests largely upon her natural advantages in iron and coal-fields. The drain of the iron industry alone upon our coal resources is enormous, and in time other nations whose coal-fields are not so readily accessible, may be able to compete with us upon an equal footing. The total coal production of the United Kingdom was 65 million tons in 1857, 101 millions in 1867, 133 millions in 1877, 157 millions in 1887, and is at present about 170 million tons per annum, of which about 34 millions are consumed in the various ironworks, and 27 millions are exported. The Royal Commission appointed to estimate how long our store of mineral fuel would last, considered, in 1871, that we might look forward to a period of 350 years before the quantity of workable coal then existing would be exhausted; but the enormous pace at which the consumption has increased would, if maintained, put that period completely out of question. Mr. R. Price Williams calculates that, with the exception of the counties of Denbigh and

Flint, all our known supplies will be exhausted by the year 1983, unless we adopt some means to economise and restrict its use. Much of the coal we burn is wasted, and thousands of tons of invaluable fuel are annually poured forth into the atmosphere of our cities. The subject is one of vital importance, and the sooner its urgency is recognised the better for the country. We ought to husband our resources, and what is equally important, we ought to set earnestly about the task of utilising the great forces of nature, the winds, the waves, and the flowing streams, to eke out the mineral wealth which is fast slipping away from us.

The late Sir William Siemens introduced some valuable improvements in the use of gas for working iron and steel, and now the introduction of water-gas bids fair to produce further economies. Water-gas is a fixed non-condensible mixture of carbonic oxide and hydrogen with a little carbonic acid. It is produced by blowing steam through incandescent fuel; the oxygen of the watery vapour combines with the carbon of the fuel, and the hydrogen passes through unaltered. The process of dissociating the steam has a rapid cooling action on the fuel, and the admission of steam is therefore alternated with that of air, to permit of recharging the furnace and rekindling the fuel to a sufficient temperature. The first plant worked on a commercial scale of any magnitude in England was erected at the works of the Leeds Forge Company, although Messrs. Pigott, of Birmingham, had made a trial of the system before that. This plant is capable of producing 40,000 cubic feet of gas per hour, which is used for various purposes in the works, such as furnace heating, welding corrugated flues, and lighting, and the saving over town gas is said to be very large.

An improving source of fuel for heating and lighting is found in the petroleum fields spread over the world. The most valuable part is distilled for lighting purposes, and the refuse used for heating. Except for smith's fires and foundry cupolas, petroleum refuse is in use for all metallurgical processes, while for steam generating it has many great advantages. Where it can be obtained cheaply there is every reason for employing it as a substitute for coal; it is very clean and safe in use, and in practical work 1 lb. of oil is equivalent to $1\frac{8}{10}$ lb. of coal. There are three methods recognised in general use for the combustion of petroleum. One consists in its reduction to gas by destructive distillation in a gas plant, after which it is burned in a manner comparable to natural gas; another method is by forcing the oil into the furnace in a spray by means of compressed air; and a third, which is the more general in its application, uses an injector, which is operated by

a jet of steam from the boiler, to throw the oil into a furnace where it is vaporised, and mingles with the air, which is also introduced by the injector.

In Chicago, coal as a fuel is being rapidly driven out. An 8-inch pipe connecting the Lima oilfields with that city, a distance of 270 miles, supplies many of the factories, and public opinion is strongly in favour of the change.

Batoum, where the Rothschilds have already invested two millions sterling in the Russian petroleum industry, is the most important centre in Europe for the importation of oil, and a similar pipe line is being laid down from the wells to the port. The two factors which have done most to develop this industry are the introduction of pipe lines, to permit of a continuous flow, and tank steamers for carring the oil in bulk. Several ships have been built by Sir W. G. Armstrong, Mitchell, & Co., capable of carrying as much as 4000 tons each of petroleum in bulk, and fitted with special arrangements to suit the trade. With 7 to 12 parts of air to 1 of petroleum vapour a violently explosive compound is formed, and great care is therefore necessary in dealing with large quantities of petroleum in bulk, to avoid such explosions as that which occurred on a petroleum vessel in Calais Harbour.

The latest statistics of this trade which have been published bring up the information to the year 1888. They show that the Russian trade has increased from 47,000 barrels in 1886 to 188,000 in 1887, and 549,000 in 1888, principally owing to the introduction of tank steamers. A similar innovation is now being made in the American trade, and the recent comparative falling-off will no doubt be speedily reversed. The total import of petroleum oil for 1888 was 1,835,274 barrels. The oil produced in Canada and Galicia is at present not more than sufficient for their home consumption. Petroleum fields in India are being rapidly developed, and those in Burmah only require capital to secure a large trade in that quarter.

Our Railways.

The Stockton and Darlington Railway, the pioneer of all the great achievements of engineers towards the annihilation of time and space, was opened on the 25th September, 1825, and, although this date is so comparatively recent, there are now about 20,000 miles of railway open in the United Kingdom, but these figures sink into insignificance when compared with the railways of the world in general, which Mr. W. P. Marshall tells us, are increasing at the rate of 17,000 miles per annum.

In 1854, at the date of the foundation of our Society, the

first rush of railway building was certainly over, and yet the Board of Trade Report for 1888 states that within the past 35 years the length of line opened for traffic in the United Kingdom has increased from 8053 to 19,812 miles, the paid-up capital has risen from 286 millions sterling to nearly 865 millions, and the gross receipts from about 21 millions sterling per annum to 73 millions, while the number of passengers conveyed has increased from 111 millions to 882 millions. Notwithstanding this large number, only 11 passengers lost their lives in the year 1888 from causes beyond their own control, and 594 were injured; in other words 1 killed in 80 millions, and 1 injured in 1½ millions. If the arts of war bring glory to a nation, the arts of peace are no less deserving of recognition, and what greater pride can a nation feel than in the contemplation of such figures as these.

In locomotive engineering much attention is still being given to the production of a compound type, which shall be suitable for ordinary traffic. At present the advantages of compounding are chiefly confined to main line traffic, as the economy is inconsiderable where frequent stoppages take place. Under favourable circumstances a saving of 15 per cent. in fuel is claimed, but against this must be put the extra cost of a compound over a simple engine. There are two principal systems now on trial in England, the Webb and the Worsdell, each having its advocates. The former has three cylinders, two high pressure and one low pressure, and the latter only one high pressure and one low pressure cylinder, and is in other respects much simpler. Mr. Webb's latest compounds, the "Oceanic" and "Teutonic," have two high pressure cylinders 14 inches diameter and 24 inches stroke, and one low pressure cylinder 30 inches diameter and 24 inches stroke, with a boiler pressure of 175 lbs. per square inch; the central and trailing wheels are 7 feet diameter. In a recent run of 1200 miles by the "Teutonic," without dropping the fire, the running speed averaged 48 miles per hour, and the average speed spread over the whole period of 48 hours was 25 miles per hour. The consumption of fuel was 34·2 lbs. per mile.

For ordinary locomotives a small though important alteration has been quietly making headway during the last four years, and is now fairly established as an adjunct to economical working. I refer to the Vortex Blast pipe, with regard to which I recently stated in public that the estimated saving in fuel made by its use on the L. and S. W. Railway alone, amounted already to nearly 50,000*l*., and as this was questioned at the time by some of the newspapers, I now append a copy of the official statement, showing that the amount is 48,461*l*.

London and South-Western Railway Company.
FUEL CONSUMPTION, &c.

Half Year Ending	Number of Engines fitted with the Vortex Blast Pipe.	Number of Engines fitted with the Plain Pipe.	Total Number of Engines.	Total Engine Miles.	Consumption of Fuel per Engine Mile.	Total Fuel Consumption.	Average cost of Fuel per Ton.	Total cost of Fuel.	Total Saving as Compared with Half Year Ending June, 1885.	
					lbs.	tons.		£	tons.	£
June 30, 1885	nil	505	505	7,501,154	29·9	100,246	13·73 shillings	72,226	..	..
Dec. 31, „	9	496	505	7,915,420	29·2	103,310		75,327	2,473	1,723
June 30, 1886	49	492	541	7,405,775	28·8	95,905		68,453	3,666	2,555
Dec. 31, „	147	389	536	8,113,054	27·9	101,368		68,871	7,243	5,048
June 30, 1887	230	299	529	7,849,983	27·3	95,821		64,164	9,111	6,350
Dec. 31, „	253	281	534	8,528,045	26·3	100,158		67,166	13,705	9,552
June 30, 1888	278	256	534	8,156,403	26·5	96,356		64,660	12,380	8,585
Dec. 31, „	301	247	548	8,508,771	26·8	102,129		69,005	11,775	8,142
June 30, 1889	324	226	550	8,166,380	27·3	99,685		64,715	9,478	6,506

Total .. £48,461

L. & S. W. Ry., Loco. and Carr. Dept.
Engineer's Office, Nine Elms. (*Signed*) W. ADAMS.

The economy of fuel is merely a subsidiary advantage, among others are the saving of a considerable mileage of pilot engines, and the increased life of the boilers owing to the efficiency of the upper and lower tubes being equalised. The L. B. & S. C. Railway and the Caledonian Railway have each about 50 engines fitted, and many other railways at home and abroad are making extended trials with a view to its adoption.

In the early days of railways, with a speed of 10 to 15 miles per hour for goods trains and 25 for passenger trains, and with engines weighing 10 or 12 tons, rails weighing 50 lbs. to the yard were ample, but the higher the speed and the heavier the rolling stock, the stronger the permanent way must be for securing the same degree of safety; and now that the speed has increased by about 50 per cent., and the weight of locomotives by 400 per cent., many of the lines have had to be relaid with rails weighing 75 and 80 lbs. to the yard. The main lines are well maintained, but many of the branch lines require attention, since the load on each wheel has so greatly increased. Mr. Sandberg's contention that the main line rails should be 100 lbs. per yard is not altogether unreasonable, although in some cases an equivalent result would be obtained by putting the sleepers closer together. According to his figures there are many instances in which the load on the driving wheel gives a pressure of 50,000 lbs. per square inch, or more than the limit of elasticity for soft steel, so that what-

ever the form or the size of the rail, it is necessary to use a hard steel, containing, say, 0·3 to 0·4 per cent. of carbon. Experience also shows that with the high speeds and heavy engines now becoming the rule, heavier rails are necessary both for safety and economy of maintenance. The accident that occurred to the train in which the Czar of Russia was travelling was reported to be due to running at too high a speed on a light permanent way, and in view of a repetition of "The Race to the North," some of the English companies may find an additional outlay required upon their iron roads. When an accident happened on the Tientsin Railway, in China, the punishment was divided over the staff and apportioned according to the rank of each, the managing director receiving the maximum punishment. The Chinese have always been known as a practical people.

Bridges.

The increased weight of rolling stock has led to the renewal of many of our railway bridges, but there is one which we trust will remain a monument, "not for an age, but for all time." The completion of the marvellous structure across the Firth of Forth is one of the memorable events of the past year, and the work itself is the most notable result of engineering skill that the world has yet witnessed. Although the cantilever principle is not new, this does not detract from the credit due to the engineers, Sir John Fowler, and our Honorary Member Mr. Benjamin Baker. From the inception to the actual realisation, the whole of the details have been so far beyond anything before attempted, that only a profound knowledge of theory and practice combined could have enabled the work to be brought to the successful issue in which we now rejoice. Every new departure from current practice involves an infinite amount of care and thought on the part of those responsible for the design and execution, and the Forth Bridge has been no exception to the general rule. It has required an absolutely continuous exercise of constructive ingenuity and inventive skill to meet the difficulties of erection; and the contractors, as well as the engineers, are to be congratulated upon the masterly way in which they have been surmounted.

Although the general dimensions and appearance of the bridge are well known to all engineers, I may perhaps put on record here a few of the chief figures. The total length of the bridge is 8296 feet from end to end, comprising fifteen girders of 168 feet each, simply as approaches to the main viaduct, which crosses the intervening space of more than a mile by two spans of 1710 feet, and two of 680 feet. The three huge double

cantilevers, forming the main feature of the bridge, each spring from a central tower formed by a group of four riveted columns of steel 12 feet in diameter, and reaching up 370 feet above the water level, braced by similar but smaller columns set diagonally on each face, and by ties and cross pieces. Each column rests upon a separate foundation, so that for the three towers twelve piers were constructed, six of which involved special skill owing to their being situated in deep water. For this purpose six iron caissons were built, each 70 feet in diameter and 60 feet high, filled with concrete and brickwork, and finished with a granite bed to receive the towers. The foundations contain in all about 130,000 cubic yards of granite, concrete, and rubble masonry. The cantilevers were built out piece by piece from the towers, the part already fixed serving as scaffolding for the next portion, and so on until completion. On either side of the central cantilevers the gap to the next is filled by a hog-backed girder 350 feet span, weighing 800 tons. The whole weight of steel in the superstructure is close on 53,000 tons and 8 million rivets hold the fabric together. The lattice portions look like lace work compared with the more solid parts, and although so light in appearance the actual extent may be estimated by the fact that the surface requiring to be painted is equivalent to an area of twenty acres. This grand work has been accomplished in the short space of seven years, with the aid of between three and four thousand men, and although several fatal accidents have happened, they have been fewer in number than might have been expected. Many illustrations have been given to show the magnitude of the structure; for instance, it takes just two Eiffel Towers, projected horizontally to make one of the great spans, and the proportion between one of the spans of this bridge and the whole span of the Britannia Tubular Bridge in length and bulk would be represented by the proportion between a large ironclad and a torpedo boat, or between a horse and a dog of medium size. But it is not in mere size that this work appeals to engineers. Light as it is in proportion to its magnitude, it is constructed to withstand a wind pressure of 56 lbs. per square foot, while the highest actual pressure recorded is only 41 lbs. per square foot, and the material is capable of withstanding from 28 to 37 tons tensile stress per square inch, while the actual stress nowhere exceeds $7\frac{1}{2}$ tons, and in those parts subject to rapid alternations of stress the actual amount will not exceed 4 tons.

During the construction of the bridge, in addition to the multifarious details necessary for its completion, the engineers have found the opportunity to devote much time and expense to many subsidiary experiments of the greatest value to the

engineering world. Not the least of these is the series of observations upon the force of the wind, which go to prove that we have habitually over-estimated its velocity and pressure, and, moreover, that the maximum effect occurs over small areas only, generally less than that of a single structure. It is satisfactory to find that the Board of Trade allowance of 56 lbs. per square foot gives an ample margin of security, and is not likely to be upset by further investigation.

The Prince of Wales has intimated to Sir John Fowler his desire to drive the last bolt in the Forth Bridge, and arrangements are being made for the opening of the bridge by the Prince on the 4th March. It is matter of general comment that the engineers deserve some national recognition for the boldness and success of their enterprise, and doubtless we may expect some public announcement on the opening day.

I am afraid that after the Forth Bridge the description of any other would fall flat, but there are some others worthy of notice. The Sukkur Bridge, over the Rori Channel of the river Indus, designed by Sir A. M. Rendel, and constructed by the firm of which our immediate past president, Mr. Baillie, is a member, has been completed during the year, and was opened in March last. This bridge consists of a single cantilever span of 820 feet over a channel 80 feet deep at low water, with an average rise of 16 feet, and a current during floods running 9 miles per hour. Until the completion of the Forth Bridge this was the largest railway bridge in the world, and was erected in 16 months by native labour without staging.

We more often hear of penalties than premiums in connection with the completion of contracts; but at Cincinnati, the contractor for the erection of a bridge over the Ohio, secured an extra allowance of 30,000*l.* by completing the work in January, 1889. This bridge is 5320 feet long, exclusive of approaches; it has two spans of 490 feet each, and one of 550 feet, and was commenced in June, 1887.

For rapid work, the great pontoon bridge over the Missouri, at Nebraska City, is worth mentioning. This bridge is 1074 feet long across the navigable channel, and the back channel is traversed by a causeway 1050 feet long supported on cribs; it is stated that the whole was built in 28 days at a cost not exceeding 3600*l.*

The Hawkesbury Bridge, opened on the 1st May, is the most important steel structure in the southern hemisphere; it has seven spans of 415 feet each, with a headway of 40 feet, and carries a double line of rail.

Among the proposed schemes for bridges to which the success of the Forth Bridge has given rise, the one perhaps

most likely to attract notice is that to signalise the World's Fair at New York in 1892. It is proposed to bridge the Hudson river with one span of the inverted arch type 2760 feet in the clear, and two side spans of 517 feet each. The road is to be suspended from an inverted arch, each rib of which will be made by bracing together in a vertical plane two steel wire cables 50 feet apart. These cables will be about 4 feet diameter, and will be carried by towers 400 feet high. The cost is variously estimated at $3\frac{1}{4}$ to 10 millions sterling.

There is a doubt at the present time which of the proposed alternative methods, if either, will be adopted for crossing the Channel. There is the tunnel under, the bridge over, and the floating tunnel through. The bridge is under the auspices of MM. Schneider and Herseul, Sir John Fowler, and Mr. Baker, and in order to remove the objections brought forward by the shipping interests in England, it is proposed to form a kind of harbour between the two banks existing in the middle of the Channel, over which the bridge will pass.

Other large bridges are proposed, such as that over the Bosphorus, but the majority are merely speculative proposals which have little chance of realisation.

Electrical Engineering.

The field of electricity as "one of the great forces of nature" is fast becoming so wide that it threatens to enwrap all forms of labour, and to accompany the production or transmission of power for all purposes. Poor old Benjamin Franklin would have hesitated to apply his knuckes to the key of the kite string, if he could have seen the enormous force now developed by means of electricity. Even within the experience of the present generation, the sole industrial applications of this power were to telegraphy and electro-metallurgy, now the transmission of power, electric haulage, electric lighting, heating, and welding, are among the many uses to which modern discovery enables us to put this unknown yet pliable force. In view of the greater dignity attaching to the electrical profession, from the increasingly numerous practical applications of its power, "The Society of Telegraph Engineers and Electricians," altered its title at the commencement of last year to "The Institution of Electrical Engineers," and if the world is looking more to one class of applied science than another, it is upon electrical engineering that the grandest hopes are being built.

Electric lighting dates practically from the introduction of the Edison and Swann incandescent lamps in 1879, although

the Gramme machine in 1872, and the Jablochkoff candle in 1876, paved the way. As soon as the practicability of electric lighting from a central station was fairly established, there was naturally a rush for the best districts in London, and a number of electric lighting companies were formed, promoting various schemes for lighting large districts, which in many instances overlapped each other. A Board of Trade inquiry under Major Marindin resulted in the apportioning of the metropolis among the principal applicants, thereby creating limited monopolies, but preventing any excessive charges by determining that the price to be paid for the use of the electrical power should not exceed eightpence per Board of Trade unit of 1000 watt-hours, or, say, 20 lamp-hours of 16 candle-power. This leaves a slight margin of profit, but some of the smaller companies will probably amalgamate as the best means of maintaining their existence. Engineers are not yet agreed as to the most economical arrangements for electric lighting; some prefer high tension reduced by transformers, others low tension; some a few gigantic engines to generate the electricity, others a larger number of ordinary-sized engines; and there is also the same want of agreement to be found throughout many of the details. The present division of the labour among various companies, working on different lines, presents a very interesting field for study; and many, besides engineers, are anxiously awaiting the result. It is satisfactory, however, to note that the directors of the Gas Light and Coke Company again report to their shareholders their opinion that the progress of electric lighting in London will not injure their business; now that so large and increasing a quantity of gas is being consumed for cooking and heating purposes, it is deemed necessary to increase the manufacturing plant at some of the company's stations.

So long as electricity was produced by the destruction of zinc, which was 24 times dearer than coal, or by any similar chemical agency, there was little chance of its adoption as a motive power; but Sturgin's discovery of the electro-magnet and Faraday's further experiments in the same direction, enabled mechanical work to be transformed directly into an electric current, so that the common modes of generating power could be applied. At the present time electricity is only a vehicle for the transmission of power, and only by reason of economies that may be introduced by its use into after processes will there be any saving in fuel consumption or the essential elements of power production.

Upon the authority of Professor Silvanus P. Thompson, as quoted in the daily press, there are 700 local electric companies

in the United States who distribute motive power to the districts around. At Rochester, New York, there are factories from which electrical power is transmitted to machines provided by them at the rate of 1*l.* 16*s.* per month for one horse-power working from 7 a.m. to 6 p.m. for six days a week, and two or more horse-power upon easier terms. The advantage of electricity in cases like this is that the power can be transmitted for 100 miles or more by a system of wires with little loss, while the transmission by compressed air, water, or steam, involves many serious losses. The straight line shafting which our ancestors depended upon in factories, from Hobson's choice, has given place in many instances to hydraulic pressure, increasing the facilities for transmitting power, and at the same time reducing its cost; but it is doubtful whether in electricity we have not found an agent which will still further reduce the cost of transmission.

It is somewhat surprising that electric traction has not made more progress in this country, seeing the great attention which has been given to it elsewhere. In the United States over 600 miles of electric tram or railway track are in use, and there are several electric tram lines in use on the Continent. The City of London and Southwark Subway Company, or the Electric Underground Railway, propose to run trains between the Monument and Stockwell, drawn by electric motors of 100 horse-power each. The motors will take their supply of electricity by means of a sliding apparatus from an overhead cable. An experimental trip made recently with one of these electric locomotives resulted in a speed of 30 miles an hour being obtained, but the working speed will not exceed 20 miles an hour. If the method of traction adopted on this railway should prove a success, and there is no reason to doubt that it will, we may expect to have the other underground railways modifying their appliances, much to the benefit of the travelling public.

On the Barking Road section of the North Metropolitan Tramways five electric cars are run daily, each doing 60 miles per day, with one change of accumulators. The saving over horse-traction appears to be between 1*d.* and 2*d.* per car mile.

Another system is in use at Northfleet, where a tram-line three-quarters of a mile in length is laid down. A slot alongside one of the rails contains contact pieces at 21 feet intervals; a projecting arrow under the car travels along the conduit below the slot, and separating the spring contacts, causes the current to traverse the motor on the car between them.

In the mines of the Lykens Valley Coal Company, Pennsylvania, a line 6300 feet long is worked by electricity on the

3-rail system; the average load is 20 cars per trip, and the amount moved 850 tons per day. The relative cost of traction per ton-mile is said to be by mule 1·82 cents; by steam 0·60 cents, and by electricity 0·40 to 0·67 cents.

Another short electric railroad worked by rope-traction ascends from the Lake of the Four Cantons, Switzerland, to the Burgenstock Hotel, a distance of 3076 feet up a slope of about 45 degrees. The power is supplied by turbines driving two dynamos at Ennerberg, 2½ miles distant, and conveyed over the hills to the upper station, where two motors work the drum over which the car-rope passes.

What is to be done with all the pipes and wires which traverse the streets above and below—will soon become a question for Londoners which cannot be postponed any longer. What with the telegraph and telephone wires, the pneumatic transmission tubes, the intermittent and constant service water pipes, the gas and hydraulic power companies' mains, and now the electric transmission of light and power, to say nothing of drains and sewerage culverts, their satisfactory disposal forms a complex problem. In Philadelphia there is a brick conduit 8 feet high and 4 feet wide, through the main streets and avenues, to take the wires for electrical purposes. There are to be fifty 3-inch pipes each containing 100 wires. The connections will be arranged so that there is one for each block, passing under the house line to the middle of the block where a tall pole will distribute wires to the rear of the houses, and thus avoid any overhead wires in the public thoroughfare. The fact that most of the accidents are reported from America is not sufficient to assure the public that there is no danger in the use of electricity, or no more than from gas, and whatever method be adopted for traversing the streets of London it is to be hoped that all the precautions which science can suggest will be duly complied with.

One of the most important of the modern applications of electricity, particularly in connection with the extended use of steel, is that of electric welding. This is accomplished by causing currents of electricity to pass through the abutting ends of the pieces to be welded; the point of contact becoming the point of greatest resistance, the greatest heat is here generated, and pressure is applied while the metals are at a welding heat. The ends to be joined are made convex so that the junction commences in the centre of the material, ensuring absolute soundness, and it is stated to be proved by tests that the weld in the case of iron and steel can be made as strong as the rest of the bar, the appearance of a fracture through the weld according with the material joined, i.e. whether fibrous or

crystalline. The machines for this purpose are made by the Thomson International Electric Welding Company, of Boston, U.S.A. As every new industrial process leads to the creation of new diseases, so we have a form of electrical sunstroke produced by proximity to the electric arc, and at the Bernardos Electric Welding Works, at Kolomo, near Moscow, special precautions are found necessary to guard against it.

Allied to electric welding is the use of the electric blowpipe, which is constructed upon the principle of the arc of an electric lamp being repelled in a given direction by a powerful electromagnet being brought near it. This ingenious instrument is the invention of Professor Sheldon, of the Harvard University.

We are a long way from ocean navigation by means of electricity, but several launches are now propelled by this means. The *Viscountess Bury* will accommodate upwards of seventy people; its length is 65 feet, beam 10 feet, draught 22 inches, and displacement 12 tons. It is worked by twin-propellers, obtaining their impetus from two Immisch motors of 7½ horse-power each, driven by 200 accumulators placed beneath the floor of the boat. Sufficient power is stored in the accumulators to carry the launch for a whole day at the highest speed allowed by the Thames Conservators, and they can be recharged during the night at various stations along the Thames. If expensive, it is nevertheless a simple and suitable mode of navigating the Thames for pleasure-seekers.

The application of electricity on board ship, as a general transmitter of motive power for all the auxiliary purposes for which steam is now employed, opens a new field for electrical engineers. By its use a saving might be accomplished not only in space and complication, but probably in actual expense also.

Although electricity is of no use for sugar refining, even in America, it is in use for bleaching, by electrolysing a solution of chloride of magnesium in a recurring cycle, and the large and costly series of experiments by Mr. Webster, which we saw in progress at Crossness, appear to prove its electrolytic value as a sewage precipitant.

One of the most recent and elegant applications of electricity is exemplified in Snelgrove's Electric Automatic Weighing Machine; but I need not describe this to you now, as a paper upon weighing apparatus will probably be placed before you at the April meeting. I have already said quite enough to show you that electricity is every whit as wonderful and all-embracing as popular belief would make it, and that it adds one more to the many interesting directions in which an engineer may devote his energies.

Conclusion.

Time was when a engineer was expected to be able to design, at a moment's notice, any piece of construction that might be required in any branch of engineering; but the specialisation that has permeated general industries has extended to professions also, giving rise to new developments and possibilities, and in most cases to such a mass of necessary detail for securing the highest efficiency at the lowest cost, that the modern engineer is physically unable to do more than master one or two of the chief branches. The old classification into military engineers, civil engineers, and millwrights, no longer indicates the scope of the requisite training, and it is more than ever necessary for a young engineer to learn "something of everything and everything of something"; that is, to cultivate a good general knowledge, but with special reference to one particular class of work, according to the direction in which his opportunities may lie. It is these altered circumstances which render societies such as this an important factor in modern progress. A member who merely pays his subscription and receives the printed 'Transactions' does not do his duty to the Society. There is a mutual obligation to meet as frequently as other engagements will permit, to interchange opinions, to contribute the results of individual experience, and by the freedom of discussion to elucidate the principles which should guide engineers in their great undertakings.

Let us take a lesson from our everyday experience as railway travellers; the rails in active service enjoy an immunity from rust, which prolongs their life and usefulness, while those in an unused siding are rapidly destroyed by the ravages of rust arising from inactivity. The benefits of personal contact are very great, and so long as the Society of Engineers maintains its present activity and the *esprit de corps* of its members, it cannot rust out; and if the body corporate be rejuvenated by the periodical addition of new blood, it will, I trust, be many a long year before it shows any signs of wearing out.

March 3, 1890.

HENRY ADAMS, President, in the Chair.

THE APPLICATION OF WATER-PRESSURE TO MACHINE TOOLS AND APPLIANCES.

By Ralph Hart Tweddell, M. Inst. C.E.

It is thirteen years since the author had the honour of reading a paper on "Direct-acting Hydraulic Machinery," before this Society. He then briefly described the results of twelve years' work in introducing his system of "Hydraulic Machine Tools," and now, in response to an invitation from your Council, he proposes, not only to refer to some of the later applications of water-pressure to the same purpose, but more especially to the hydraulic labour-saving appliances now so generally employed in constructive engineering work. The close of the first quarter of a century in the history of any new industry seems a fitting occasion to review its development, to consider its present position, and to look forward to its future extension.

The necessity of explaining the principles which govern the economical distribution of hydraulic power no longer exists. The author discussed these points in his previous paper, and the results since obtained, and about to be described, are confirmatory of the correctness of the views then expressed.

In 1877, the date of his previous paper, it was needful, in order to justify the introduction of hydraulic riveting machines, to compare them with those which were then in general use, these being, as a rule, worked either by gearing or steam. Now both of these types are practically extinct. In 1877 the author was only able to record the results of the working of one or two hundred machines. Now this number is increased twenty or thirty fold. Stationary riveters have been increased in power from 30 or 40 tons to 200 tons. Portable riveters, which had until then been chiefly used for girder work, and on one or two bridges during erection, are now used on every bridge of any magnitude, and every rivet can now be put in by machine in either land, locomotive, or marine boilers. All plates can now be flanged by power, irrespective of their thickness or size.

Hydraulic "forging" is now constantly specified, and even drilling and similar work has been proved to be, under suitable conditions, most economically done by water-pressure.

Since, however, the superiority of water-pressure, as a motive power for these purposes, is now in its turn sometimes questioned by the advocates of air or electricity, it is necessary, briefly, to consider their relative merits. The present application of either of the latter systems is only very limited, and however ingenious and well worked out in detail each machine may be, it must to a great extent continue to be so.

The conditions to be fulfilled in the designing and successful development of a complete system of machine tools or appliances are very different from those affecting a simple machine tool. A motive power which may be suitable for the latter, may fall short in many ways when applied to the former. In considering the relative merits of water, air, or electricity for working a system of machine tools, a much broader view of the question must be taken than that of their respective fitness to perform any one mechanical operation. Provided enough power is applied, there is no reason why, for example, many operations should not be as well done by one machine as the other. It is quite another matter when we come to consider the relative cost of the work when done, and the relative convenience of applying the power, not only to one, but to several tools. So far as the tool itself is concerned, this depends, of course, on many details, such as fewness of parts, and, in the case of portable machines, lightness, both of these conditions involving directness of action and simplicity of construction.

The peculiar suitability of water-pressure as a means of distributing power over great distances is well known, but its adaptability to exerting the smallest or the largest effort with equal facility after being so distributed is often lost sight of. In comparing this power with either air or electricity, it is this feature which makes it especially suitable for the class of work under consideration.

The tendency in all modern constructive work is to increase its size, and to send it away from the shops in as large pieces as possible. This of course often renders it impracticable to take the work to the machines, and consequently portable machines, for such purposes as riveting especially, are indispensable. But there is not only an increase of weight in the work to be done. Every other dimension is thereby also increased. For example, the width of plates and the size of rivets, the objects in both cases being to reduce the number of joints and details. All these make it necessary to have heavier machines, so that the result is that portable riveters in some cases are now larger

and heavier than the stationary ones of 25 years ago. To manipulate these, of course, some mechanical power is absolutely necessary, and hydraulic power is at once the simplest and safest, being absolutely under control, and capable of the most minute adjustment. At the same time it is not only applicable to all the lifting apparatus used in connection with the riveting machines, but to the working of capstans, hoists, and the other labour-saving appliances now absolutely necessary to reduce the cost of transporting material in any properly laid-out works.

Perhaps, however, the relative merits of these three modes of distributing power to the class of work under consideration can best be shown by stating the conditions to be fulfilled, and by seeing which system complies with them to the greatest extent.

Briefly, the conditions are—

1st. Convenient generation and storage of power adaptable to exerting the lightest and heaviest pressure simultaneously.

2nd. Economy and facility in distributing it over large areas.

3rd. Simplicity in its application to the different tools, and to the appliances required to take them to and from their work.

4th. Adaptability to perform work of the lightest and heaviest description.

Condition 1. The question of the convenient storage of power must be considered in connection with its suitability for being drawn upon to meet demands of ever-varying amount of power, and there can be no doubt as to the superiority of hydraulic pressure for fulfilling this condition. In fact, by neither of the other systems can such different operations be done simultaneously, such as closing a rivet with, say, a pressure of 5 tons, flanging a plate with, say, 300 tons, or forging a shaft with 3000 tons pressure, all from one accumulator. As a matter of fact, the hydraulic system is the only one of the three by which either of the latter operations can be performed at all.

Before dismissing the subject of storage it may be pointed out that, owing to the high pressure which can be employed with water, the room occupied by the accumulator is very small in comparison with its storage capacity, and when properly proportioned to the size of the accumulator, a much smaller prime mover can be used than with any other system.

Condition 2. Economy and facility in distributing the pressure over large areas.

All three systems possess certain advantages and defects, and perhaps on this head it would be difficult to offer a decided opinion, as each may be best under certain conditions. This

being so, it is evident that the system which can do the most work after it has been distributed, must be the best, and that water can fulfil this condition has already been demonstrated.

Condition 3. Simplicity in application to any appliances required to take the machines to and from their work.

On this head, since the water required to work the lifts can be taken direct from the pressure mains on its way to the machine, it can be applied in the most direct manner, and gives the greatest facility for the adjustment of either the tool or the work. Compressed air is utterly unsuited for this purpose, and electricity involves many complications.

Owing to the high pressure available when water is used, the power can be applied to its work in the most economical, because in the most direct, manner. The exact power applied is known, and all the want of rigidity and accuracy, which follows in the train of any system in which the power is multiplied by means of levers and gearing and fly wheels, is avoided. On the score of simplicity, no system can be compared with water-pressure machines. Thus, while air and electricity comply with some of these conditions, they do not fulfil those among the most important in connection with the requirements of the work under consideration.

On the other hand, hydraulic pressure not only fulfils all the conditions, but it is especially applicable to the working of machine tools and their means of adjustment, and also to the appliances for taking the material to and from them.

Time does not permit the further consideration of these interesting comparisons, and the author must now pass on to a description of some of the more recent types of machine tools, stating, at the same time, some of the reasons for their design.

The pressure of steam carried in the boilers of the present day has necessitated the use of steel shell-plates, not only of a stronger quality but of greater thickness; and in bridge construction also, makers have availed themselves of the power of the hydraulic riveter, not only to use stronger material, but to multiply the number of thicknesses. The result in both cases is that it is not now so much the diameter of the rivet which regulates the power of the riveting machine as its length. A long rivet means either a few very thick or a large number of thin plates, and in both cases the greater part of the increased power is that required to bring and keep the plates together while the rivet is being formed or headed. Hence there arose a demand for a "plating machine"; and since the operations of bringing and keeping the plates together and closing the rivet ought to be done as simultaneously as possible; it was found best to combine them in one machine. The first machine to do

this work practically was designed by the author and Messrs. James Platt and John Fielding in 1880, and a large number of them have since been brought into use. The principle is this: by means of two rams (Fig. 1), one inside the other, a pressure in the first place is brought to bear on the plates by means of an annular tool A, encasing the moving cupping disc B; when the plates are thus brought together, the cupping tool heads the rivet, and after this operation is performed, the combined power of both rams C and D is applied on the head of the rivet and through the shoulders of same on to the plate surrounding it. The size of work is only limited by the power of the machine, but some very good work in "cold" riveting up to 1 in. diameter has been done by these machines, and it is probable, in the author's opinion, that the next improvement in this part of boiler work will be the use of cold rivets, having not only the holes drilled but the rivets themselves turned. An incidental advantage of the arrangement of the plate-closing riveter above described is this, that by substituting a riveting die for the annular closing tool A, a second and smaller power is available; this adds very much to the general use of the tool, for it is impossible to keep such a powerful machine in constant work, and of course the power is too great for the thinner plates of boiler furnaces and combustion chambers. Excellent work has been done by this machine when using plain bolts, in making both heads of the rivet in the act of closing it. This machine is capable of exerting three different powers, which is a great advantage. Although these machines are made up to 150 and over 200 tons power, very little more high pressure water is required owing to the use of an auxiliary piston E, which draws forward, by means of the lug F, the two main rams C and D, the space left behind being filled with low pressure water through check valves G and H, from a tank L.

Whatever may be the defects of the present type of marine boiler, it so far holds the field; but it is equally certain that without hydraulic riveting this type of boiler could never have been made tight, or the triple and compound engine have been carried into practice, and we should not have seen the present ocean steamers carrying 170 to 200 lbs. steam, and continuously and uninterruptedly performing their voyages.

That this is so is proved by the demands of boiler makers for a portable hydraulic riveter to complete the work of the mechanical riveting by riveting up the closing-in ends also. When the flanges are made outwards, this is done by a portable riveter fitted with plate-closing gears. Some engineers, however, do not approve of this style of joint, and prefer the old plan of putting the boiler ends in with the flanges turned inwards.

This at first seems a difficult problem to solve, but it has been done, on Fig. 2, by means of a machine with a hinged arm A, which is first of all lowered into the boiler, and when restored to its proper position A^2, the riveting is proceeded with.

To meet the requirements in portable riveters of increased size and power, and yet secure rigidity in the machine itself, Mr. John Fielding has designed a very neat connection between the ends of the levers opposite to those carrying the riveting dies. By means of a curved ram working in a cylinder of similar shape, a very simple and direct connection is obtained, and thus is obviated the necessity for a connecting rod or strut, and the machine is made practically as rigid as the old solid-casting or "bear" form, the cupping dies being all clear to get into confined and awkward work (see A, Fig. 3), the same as on the original portable riveters invented by the author in 1871. A passing allusion was made in the author's previous paper to the first practical application of his portable hydraulic riveting machines to the riveting up of a bridge *in situ*, namely the Primrose Street Bridge, London; this was 17 years ago. To-morrow the last rivet of the Forth Bridge will be closed, and the bridge itself declared open by H.R.H. the Prince of Wales. The application of hydraulic pressure to the erection and riveting of this bridge, is the latest and most perfect adaptation of this system, and it is not too much to say that, but for the use in many different directions of hydraulic pressure, the bridge could not have been built in the time, if at all. By the courtesy of Mr. now Sir Benjamin Baker, photographs of some of the machines adopted will be shown on the screen. Photographs will also be shown of similar work done on the Primrose Street Bridge, and will, the author thinks, show that the feasibility of doing such work by hydraulic pressure was first proved by its application to that bridge in 1873. Since then similar work has been done on the Dufferin Bridge at Benares, of which photographs will be shown. While riveting the bottom boom flanges and general web and gusset work of this bridge, each portable riveter closed 850 steel rivets 1 " diam " per day, and about 900 per day on the flooring plates. Figs. 3 and 4 show a similar travelling crane. The crane carries a portable riveter A, and by means of cross-girder B this riveter is moved across the floor, and the crane, with its rivet-heating furnace, is traversed along. It has been stated that but for hydraulic riveting the Dufferin Bridge would have taken another twelve months, if not more, to build. Besides this bridge, the Sukkur Bridge, built by Mr. J. R. Baillie, and a very large number of other bridges in India, America, and Australia, have been done by these machines, and in many cases

there has not only been a saving in the cost of riveting but in that of labour in handling the material, a great deal of which has been done by hydraulic cranes worked from the same accumulator. When a number of small bridges along a line of railway require riveting, a hydraulic transport train is sometimes used. Figs. 3 and 4 show a portion of such a plant, sent out for this purpose and used by the late Mr. Arthur Sullivan on the railways on our Indian frontier; in this case pumps, accumulators, and cranes are on separate trucks. On some of those bridges the portable riveter A, Fig. 3, closed 4000 rivets per day. It is impossible, in the space of a paper, to go further into the various applications of portable riveters, but for the riveting of gun-carriage frames, railway wagons, portable engine wheels, wrought iron or steel sleepers, and other work, many hundred machines are now used. One of the most recent applications is to the riveting of steel pipes for waterworks, &c. In a plant recently erected, some of these machines put in 4050 rivets each in 11 hours.

Allusion has been made to the great increase in the power of stationary hydraulic riveting machines; and as regards this increase the author considers it to be unnecessary, or at all events to such an extent. Their adoption is due to two causes, viz. first, trade rivalry: A wants to have a bigger machine than B, and of course gets it from somebody. And again, if closely looked into, it might be found that the real reason for putting on so large a pressure was that by so doing it was hoped to make good the defects due to bad flanging by hand and indifferent plating. This might be done to a certain extent when plates were thin, but now it is impossible, hence the general adoption in all first class work of hydraulic flanging. The author may mention, while on the subject of the "amount of pressure" required to close a rivet, that he recently saw a boiler tested in which the shell plates had been riveted with a power of 100 tons (imparted through a toggle joint) and the end plates riveted in with only 40 tons pressure, applied with a direct-acting ram. As anyone knows the second operation requires much the greater pressure, since the flanges are very stiff, but the work done by the 40 tons was equally tight and good in every respect.

Flanging.—The question of flanging was not referred to in the author's previous paper; flanging or pressing a plate in a press is, of course, a very old idea, but when it emerged from the region of stamping small metal goods, and such as Birmingham ware, it became necessary to modify the press. This was done by adding another cylinder or cylinders, which through the intervention of a vice-plate, gripped the work to be flanged and prevented buckling during the process. These

presses generally had four columns, and the diameter or size of any plate to be flanged was limited by the centres of these columns. As work grew larger, the dies became unwieldy and at last too costly to allow of the work being done at a profit. When the thickness of marine boiler end-plates reached $1\frac{1}{4}$ to $1\frac{5}{16}$-in., with flanges 12 inches deep, hand work became impracticable, except at a ruinous cost. In the year 1880, quite a new departure was made, in the introduction by the author, together with Messrs. Platt, Fielding, & Boyd, of a type of machine (Figs. 5 and 6), which, for want of a better title, is termed the step-by-step or progressive flanger.

It is well known that no marine boiler designer, with a proper sense of self respect, will modify by a single hair's breadth the shape or dimension of a single plate in his boiler in order to adapt them to meet the sizes of any dies or blocks the manufacturer may have in stock; therefore, any machine which would enable the boiler-maker to meet this difficulty, was sure to prove of great value. The mode of working is as follows:—instead of using a die the size of any circular plate to be flanged, a block, A, forming a small segment only of this circle is used, and the plate being placed upon it, the outer ram B, descends and fixes it there, while the inner one, C, in its descent turns the flange over, the plate is then moved forward and the operation repeated for the length of plate heated. Then the inner vertical ram being raised up out of the way, the flange is squared up by means of the horizontal ram D. Flanges are thus made 12 inches deep, and on plates of any diameter. When it is desired to form the flanges for furnace mouths in front plates, the two vertical rams are coupled together by means of the die (E, Fig. 6) itself. The economical result as compared with hand work is, that the same amount of work is done in half the time and at one half the cost, the material itself being much less strained. The work being so accurate when done, there can be no question but that a tighter rivet is made with two-thirds the power than would be the case were hand flanging depended upon.

Hydraulic Forging.—In 1877, but few engineers had much faith in hydraulic power for this purpose, but now the steady pressure of the hydraulic press is admitted on all hands to be the best, both for the material being worked and for economy in cost of manufacture. Presses which did their work by forcing the material into moulds, such work for example as axle boxes, bosses of wheels, &c., have been so made for many years, but it is only recently that hydraulic forging presses, properly so called, have come into use, these vary from 50 to 5000 tons power, and are used to draw down the heaviest steel shafts,

&c., acting in a similar manner to a steam hammer, the only difference being that the hydraulic hammer head has comparatively no fall, but does the work in a number of short strokes, in fact kneads the material, and thus brings it down to the required shape. In all the presses hitherto made there is a great deal of top weight and not sufficient means of varying the power to suit different classes of work. Fig. 7 shows the type of press introduced by Messrs. Fielding & Platt and the author, in which these defects are overcome; a clear head-room is given for cranes, and as the three cylinders A B C are all below ground, the machine is very rigid and stable; the three cylinders used admit of a very ready alteration of the power exerted, and more complicated forgings can be made, owing to the moving anvil-block only being above the shop floor.

It is only possible in this paper to allude to some of the more recent applications of hydraulic pressure. The operation of drilling, at first sight, does not appear one suitable for hydraulic powers, nevertheless, the machine designed by Monsr. Marc Berrier-Fontaine has been found very useful, and is in extensive use; it consists in the use of an hydraulic engine, in some cases working the drill direct, as in Figs. 8 and 9, where it is seen applied to a double-acting drill for boiler rivets; in others, through a Stow flexible shaft (see Fig. 10), where A is the hydraulic motor, B the flexible shaft, and C the drill head. The machine is of course chiefly useful where no other drill can be applied. In such cases the speed of working, compared with hand work and ratchet brace, is from seven to ten times in favour of the hydraulic engine. In one instance, in a boiler shop, the cost for drilling holes was reduced from 1*s*. 4*d*. to 4*d*. per dozen, besides being done much faster. Working on the shell of H.M.S. *Victoria*, at Elswick, work which required three hours by hand was done in 12½ minutes after the drill was fixed, while in some very cramped places in the wings, the machine did in one hour work which required 10 hours to do by hand. Figs. 11 and 12 show the same action applied to a portable apparatus for cutting out manholes up to 30 inches diameter, or oval if required, in ships' decks.

The great increase in the thickness of marine boiler shell plates, has severely strained the capacity of bending rolls, and their inability to roll a plate to a true curve to the end renders it difficult afterwards to make the riveted joints. It occurred to Mr. Eltringham, of South Shields, to use a horizontal hydraulic press for this work, fitted with dies shaped to the radius required, which overcame the latter difficulty entirely, and as the workman cannot feed in the plates too fast, and thus choke the machine, the risk of fracture is altogether avoided. Figs. 13

and 14 show an improved form of this press, made by Messrs. Fielding and Platt, under a patent granted to them and the author. The dies A and B are brought up to each other by means of a special parallel motion worked by hydraulic cylinder C; several of these machines are at work very satisfactorily.

In conclusion, the author would offer a few remarks on the importance of the use of labour-saving appliances in connection with machine tools, not hydraulic only, but of all kinds. As already pointed out, hydraulic pressure is the best for this purpose. One indirect benefit resulting from the introduction of the author's system has been that hydraulic lifting appliances, have been very extensively adopted to work over geared machines, in shops even where hydraulic machines are not in use. For example, the output of, say, such a tool as a geared double-ended punching and shearing machine, is thus greatly increased; in fact, in practice, it enables two machines, to do the work of three. The type of crane or hoist varies, of course, very much, and hydraulic machinery of this class is the most readily adapted to meet such varied conditions. A very useful and simple form of crane is that shown in Figs. 15 and 16, the hydraulic lifting crane A, working in a cylinder B, fitted between the crane posts C C, raises and lowers the jib. No engineer can pass through a machine shop without noticing the number of machines practically idle, i. e. waiting for the work to be taken to or from or adjusted on them; one crane judiciously placed to command three or four machines will prevent all this, and increase the turn-over, probably from 20 to 30 per cent. per week. In these days of keen competition not a casting or forging should go twice over the same ground, but from its entering the shops as raw material, its progress should be direct to the wagons taking it out as a finished product.

DISCUSSION.

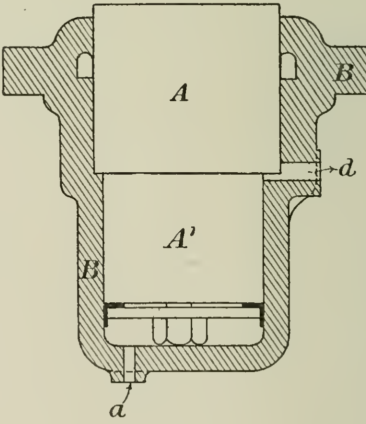
The President said that what Lord Armstrong had done in general hydraulic machinery, Mr. Tweddell had done in the special application of hydraulic power to machine tools. Apart from the great value of the paper to the Society, it was a matter of personal gratification to him (the President), on account of his connection with hydraulic machiney, that the first paper during his year of office should be one on that subject; and he was sure that the members would agree that the details had been placed before them in a very interesting manner. A new departure had taken place this evening in the

method of illustration. He had much pleasure in proposing a vote of thanks to Mr. Tweddell for the paper which he had read; and on this motion being put to the meeting it was unanimously passed.

Professor HENRY ROBINSON said that he had not come to the meeting with the intention of taking part in any discussion, for he regarded Mr. Tweddell's description of his tools as hardly involving discussion, and to criticise it would be out of place. He had seen in operation the appliances which had been described in the paper, and during his connection with Lord Armstrong's works many years ago, he had been a witness of Mr. Tweddell's earnest endeavours to perfect those labour-saving appliances with which his name was identified. Those persons who knew the difficulties which manufacturers had to face now-a-days in connection with labour must appreciate the enormous safety which a manufacturer must feel in being able to do so large an amount of his work by means of machinery which was almost invariably worked by unskilled labour, instead of having to depend upon large numbers of skilled hands. He thought it was fortunate that the author had not carried out his idea of making a comparison between the various modes of transmitting power, for this was far too large a subject to be dealt with in a paper. There was really no need for rivalry between the different systems, and it only arose when interested people unduly advocated one system over another. Each method had a sphere of its own, and before deciding in favour of one system, all the circumstances and conditions required to be studied skilfully and impartially. Engineers must be on their guard against following up the advice of advocates of any system.

Mr. GEORGE A. GOODWIN said that the paper was of a character which prevented discussion. It was full of facts, and described machines which were about the best of their respective class. He thought that scarcely sufficient had been said as to the safety inherent in the use of hydraulic power. That was a point of very great importance. If anything gave way there was no extraneous damage done similar to what would take place if a compressible medium such as steam or air had been used. There was one point in which he did not agree with the author, and that was, that with the hydraulic machinery a very much smaller motor could be used than with other mediums. If electricity was employed, a smaller motor could be used, because a greater power could be stored, as in secondary batteries, than what would be available in an hydraulic accumulator, and the motor could go on storing continuously, whereas hydraulic engines and pumps, so far, have only been made to

work during such times as the stored power is below its normal capacity. He had often wondered that more was not done in the way of economising the water required for working hydraulic plant, for instance, in the plate-closing machine described by the author, this could easily be done. In riveting up plates, pressure was exerted first to squeeze the plates, and the piston would be advanced. The space thus left in the cylinder should be filled up with dead water from a tank, so that when it was desired to put on the second pressure they would have to admit only a very small quantity of pressure water to produce the full effect due to the diameter of the ram. By that means a large amount of pressure water would be saved, which, of course, was a very great consideration. He had been lately consulted by one of the South of England Harbour Boards about adopting either hydraulic machinery or steam-power to their quays, and recommended hydraulic machinery, the total cost of which was estimated at 13,561*l.* as against 11,116*l.* for steam machinery to do the same work, but the estimated cost of working in the case of hydraulic power was 41 cwt. of coal a day, and in case of steam it was from 112 to 120 cwt. Again, in the case of steam a large amount of fresh water would be required for evaporation in the boilers, while in the case of hydraulic power the consumption would be very small indeed. Condensing engines would be used, and the condensed steam would be returned to the boilers. The pressure water would either be sea water, which was free, or fresh and made to circulate.



Mr. Goodwin drew upon the blackboard the above sketch of an hydraulic ram, which he had made for the purpose of econo-

mising water without entailing any complication. A A^1 is a differential ram working in cylinder B. For a first pressure, water is admitted by the opening *d* to the annular space between A and A^1, and while the ram is rising, dead water is drawn into the lower end of the cylinder; when the full pressure is required, high pressure water is admitted by *a* to the bottom of the ram, thus putting the full area into operation. It will be seen that this system does not require any extra moving parts, with the exception of a double valve for a riveter and plate closer. A could be made independent of A^1 to act as the plate closer, while A^1 could act as the riveter. This appliance Mr. Goodwin has used at high pressures up to about one ton per inch, and a considerable amount of high-pressure water had been saved.

Mr. F. E. Duckham said that he wished, as an engineer, to express his sincere thanks to Mr. Tweddell for the very valuable information which he had given, and, as an Englishman, to thank him for the advances he had made in tools which enabled engineers to carry out works that would otherwise be impossible. There could be no doubt that, for the majority of purposes where great power was required, such power could be obtained more conveniently by hydraulic pressure than by any other means. Hydraulic riveting was certainly better than hand work, and he was of opinion that in the matter of welding, a much better connection was made between two masses of heated iron by hydraulic pressure than by a succession of taps and blows. The paper contained very little that could be criticised. The tools which had been so graphically described were in existence, and were already most successful. Mr. Tweddell had referred to a French three-cylinder arrangement for working a drill. For some years past he (Mr. Duckham) had, on the works with which he was particularly connected, a very satisfactory rotary engine, that had been introduced by Mr. Rigg. One of these was connected with a hydraulic capstan, and another of the same kind was being tried for driving a dynamo for electric lighting. One great advantage of Mr. Rigg's engine was that the amount of water consumed could be regulated to the work which the engine was doing. In working it for electric lighting, the idea was that the dynamo should be put upon a truck with Mr. Rigg's little engine attached, so that it might be taken about the dock and connected with the hydraulic pressure main wherever wanted, and it had, sometime since, been suggested that such a tool would be a most convenient one for drilling on board ships and in cramped places where ordinary power machines could not be used. Perhaps Mr. Tweddell could give them some

information as to the loss of power by friction in his hydraulic machines.

Mr. Ewing Matheson said that while he fully appreciated Mr. Tweddell's methods, and while he agreed with a former speaker that this was hardly the proper opportunity for comparing different methods of transmitting power, he might be allowed, in connection with the question of riveting, to say a word about compressed air, with the view of illustrating Mr. Tweddell's opinion on some of the more recent applications of it. A few years ago the only way in which, to his knowledge, compressed air was used for riveting, was by applying a comparatively feeble power to the end of the rivet by a succession of light blows, as in a rock drill. This undoubtedly did effectually close rivets of moderate size. Of course this could not compare at all with the great force of hydraulic power, both for riveting and squeezing the plates together, nor apparently was it applicable to large rivets; but during the last few years compressed air had in England been applied to riveting in an entirely different way, and he believed that in some of the large bridge works it was being worked side by side with Mr. Tweddell's riveters. He was himself a firm believer in the hydraulic system, but still one should not ignore the fact that at the present moment a very large amount of long rivets were being effectually closed with compressed air, a small gas engine, compressing the air, being placed as nearly as might be to the work to be done. With regard to electricity as a means of transmitting power, there might be seen in London at the present time, rivets heated in their places by electricity. The rivets were plain bolts without a head; they were put in their places, and a current of electricity being applied through the rivet closers (which served as conductors), the bolts were made white hot and brought as near to fusion as wrought iron would allow, and then the rivets were closed. The quantity of electricity in amperes was very great, but the tension was very low, only three volts, and so feeble a current being impeded in passing through the bolts rapidly engendered heat, the bolt becoming white hot in about ten seconds. He thought that it was not at all improbable that in the next year or two they might see the heating done entirely by the electric current, in connection with the hydraulic rivet closer. Apparently this plan would be very convenient where it would be awkward to take a rivet forge, or where the rivet would become nearly cold while being carried from the forge to its place. He believed that it had been clearly proved that electric heating could be done at less cost, and with much greater convenience, than heating in the ordinary way. If anybody

present wished to see the process he should have very great pleasure in showing it to him.

Mr. Arthur Rigg said that Mr. Tweddell was really the pioneer of the use of high pressure hydraulics to such appliances as the riveting machines which had been described to the meeting in so interesting a manner. Yet it must be admitted that at present they were scarcely beyond the infancy of hydraulic tools, and it appeared to him that before long they would have large numbers of machines in which hydraulic power would be directly employed. Why, for example, should it not be used to drive printing machines? In such directions as this there was an immense field open, and if people were not so afraid of high pressure, there seems no doubt that hydraulic machines might become the means of causing great transformations in many works besides shipyards.

One difficulty with hydraulic power had always been to regulate the amount of water used in accordance with the work required to be done. In nearly all hydraulic engines or hoists which had been brought out, the amount of water used was just the same whether lifting the chain alone, or lifting a full load, and this was an evil which he (Mr. Rigg) had been endeavouring to overcome, so far as hydraulic engines were concerned, and he had also been seeking to make a new departure in hydraulic engineering by introducing high speed, and this was so successful that they could now make hydraulic engines to run to as much as a thousand revolutions a minute. Mr. Tweddell had devoted himself to one branch of the subject, and he (Mr. Rigg) had taken up another. He believed that both branches were progressing as well as possible, and he would conclude by repeating that the Society was very much indebted to Mr. Tweddell for bringing before them his interesting and beautifully illustrated paper.

Mr. John Fielding said that he wished to express the pleasure which he had felt in seeing represented on the screen old friends in the form of appliances, which he had been jointly interested with Mr. Tweddell in bringing out. Mr. Goodwin, in referring to electricity as a motive power, had spoken of the possibility of using a smaller motor to effect a given purpose. He thought, however, that it had been pretty clearly shown that so far as regarded the machine tools to which Mr. Tweddell had applied hydraulic pressure, electricity would be utterly unsuitable. He did not see how electricity could furnish such pressures as 3000 or 6000 or even 100 tons.

Mr. Goodwin said that he alluded to means of generating powers.

Mr. Fielding said that Mr. Goodwin had mentioned the

possibility of having some means of economising water. It must be fairly admitted that, whilst the resistance of the ram was less at some parts than at others, they had to provide for the maximum pressure being exerted, and that was the objection to hydraulic pressure in such cases. It was, however, only a question as to how far it would be permissible to complicate a machine, since there would not be any difficulty in designing a machine which would transmit a pressure in all cases approximately equal to the resistance which was being offered. But "simplicity in all things, proverbially in mechanics," was an axiom laid down by James Watt, and in the present matter simplicity was a most important consideration. The power was generated so economically that it was not of very much importance if a little of it was wasted in the machines under consideration. It was unnecessary to point out that to generate air pressure, there was a good deal more power wasted than in generating hydraulic pressure. The heating of rivets by electricity was a most interesting question, and the only doubt which he had on the subject was as to the possibility of doing so economically. However, Mr. Matheson had explained that the electric heating was cheaper than the present system. As to high-speed engines, he (Mr. Fielding) had been interested in such matters, having made a high-speed hydraulic engine running up to a thousand revolutions a minute, but he must confess to a sense of failure, and he was bound to admit that he did not think that the high-speed engine was likely to be a successful application of hydraulic pressure. The loss by friction, caused by the velocity of the water in the passages, was very great, and this was the principal reason why such engines were not successful in practice.

Mr. Halpin said that he could not agree with the last speaker in his remarks about the impracticability of high pressure water being used for producing rotative power. He believed that it could produce it very economically, but not by means of a reciprocating engine and piston; he did not know any more efficient machine working at high pressure than the turbine. He believed there were instances of this in what was considered a very primitive form of machine in America, working at 700 or 800 lbs., called a hurdy-gurdy wheel, and giving efficiencies up to 80 per cent. The motion was direct and continuous, and there was no effort made to reverse the motion of the water. He differed from Mr. Fielding with respect to the waste of water in the cylinders of hydraulic machines being unimportant, and he thought that it ought to be avoided. He had lately had an opportunity of really measuring what the waste of steam used to produce this water under pressure came

to, and he found that in one case they were using as much as 160 lbs. of steam per horse-power per hour. He thought that that was rather high for any kind of steam machinery. The paper alluded to the use of cold rivets. That was a matter which should be approached with the greatest possible caution. They all knew that cold riveting was done in stove pipes and things of that kind where it did not matter if the joint was not tight; but in the case of boilers, where the stresses were enormous, the subject of cold riveting should be very cautiously approached, as there was at present, as far as he knew, no data concerning the flow of iron under these conditions.

Mr. Perry F. Nursey said that Mr. Tweddell had stated in his paper that twelve or thirteen years ago he read a paper before the Society, in which he gave the experience of twelve years' previous practice. He (Mr. Nursey) well remembered that paper, and the amount of argument then necessary, even after twelve years of working, to bring conviction to men's minds of the usefulness and economy of hydraulic power as applied by Mr. Tweddell. Since that time great advances had been made, and he (the speaker) could hardly go into any engineering works without coming across Tweddell's machines. He had seen them busy at work on the Forth Bridge, first on the lower portions and lastly on the topmost parts of the superstructure. He had seen various kinds of Tweddell's machines in use for the last seventeen or eighteen years past, and he had seen them under all conditions of work, and had long been convinced of their practical value. With regard to electric welding, he had recently inspected that process, and he could testify to having seen the rivets successfully heated and closed. He would not say that they were closed in the most perfect manner, but they were heated most rapidly. He thought that Professor Thomson's system of electric heating, and Mr. Tweddell's system of hydraulic closing would about fit in with each other, if they could be conveniently brought together, which he (Mr. Nursey) had no doubt they would be. As to cost, he had not any doubt that electric heating would come out most reasonably wherever there was a large amount of work to be continuously done; for occasional or intermittent work the cost would come out high.

Mr. Alfred Slater said that at the works with which he was concerned, the hydraulic riveting plant had been in use for some years, and had proved much less expensive than hand riveting, although the work for which it was used was so light that hand riveting could have been employed, and although, further, they had to change frequently from one size of rivets to another, which necessitated the changing of the machine. Making ample allowance for the cost of maintenance, the

expense of hydraulic riveting was only about half that of hand riveting. With regard to maintenance, he had found a little trouble with one or two parts of the machine, and particularly with regard to the leathers. That was the only fault which he was disposed to find with the plan. On the whole, the hydraulic machinery was most economical and most useful.

Captain BATE, R.E., said that he wished to hear more especially whether there was any chance of their being able to obtain an hydraulic engine which would compete, as regards speed, with an ordinary high-pressure steam engine. He had had occasion lately to look into the matter of the transmission of power in connection with some work that he had been engaged upon, and he had compared hydraulic power, compressed air, and electricity. In the case of the latter, he found the expense of storage to be so enormous, as to store 120 horse-power for twenty minutes would cost nearly 3000*l.*, that it put the use of electricity in his case out of the question. With air, of course, the storage was possible, but there was a very great disadvantage in certain cases in working at such low pressures as 60 or 80 lbs. instead of the ordinary pressure used for hydraulic work, say 750 lbs. All knew what would be the result if they tried to work air at that pressure. He should like to hear from the author some data for comparing air with water. For instance, what was the loss of efficiency from the steam engine to the hydraulic motor? And what was it with air as the medium of transmission of the power? Also a comparison of the speeds that could be employed with each.

Mr. R. H. TWEDDELL, in reply, said that he had a difficulty in answering some of the questions, on account of their great scope. As he stated at the end of his paper, it was impossible to go into all the applications on which a comparison could be based of air, electricity, and water transmission. With him the first consideration always was, what was the nature of the work to be done, and then he endeavoured to find the simplest way of doing it. With regard to the transmission of power, the question in all cases resolved itself into what was to be done. The difficulty in making a comparison lay in the variety of the ends to be attained. He did not think that any one system could be applicable to every case. In London, for example, hydraulic power was used to take people with their portmanteaux to the upper floors of hotels. In Birmingham what was required was small powers for driving all kinds of domestic machinery, and motors for small industrial establishments. As to the question of the friction of leathers, that was a point which had always been very anxiously inquired about. His own experience as to the friction of leathers was that it was so slight in proportion to the enormous power exerted by the

machines themselves that he never took it into account on any consideration whatever, and he did not think that this point was taken into consideration in any machinery of large size. In reference to what has been said by their President, he could only thank him for his kind remarks, which he greatly valued, and for his approval of both the matter and of his mode of illustrating it. With Professor Robinson he quite agreed that this was not the occasion to enter into a close comparison of the various modes of transmitting power, but he could only hope that Professor Robinson—than whom no one was better able—would give the Society an opportunity of discusing this question. In reply to Mr. Goodwin, the question of safety was so well established that he had not referred to it, but it was, of course, a most valuable feature. In reference to economising the consumption of water, several similar applications to that sketched by him had been employed by the author. Mr. Duckham had referred to Mr. Rigg's hydraulic engine. One of the great advantages of such discussions was the bringing forward of different methods of arriving at similar ends, the inventors standing somewhat in the position of prisoners at the bar, with the audience as jury. With reference to Mr. Ewing Matheson's remarks on pneumatic riveting, it must be observed that this never became practicable or feasible until by means of levers and toggle joints they obtained, but in a most complicated, wasteful, and uncertain manner, a similar steady pressure or squeeze to that exerted in a direct manner by hydraulic pressure. Even then the idea is old, and was patented by the author, with others, in 1873. As regards the electric heating of rivets, this could of course be done, and circumstances might occur when it would justify the expense. Electric welding was another matter, and, when an enormous repetition of similar welds had to be made, was an undoubted success; but after all it was only a heating apparatus, as they had to depend on hydraulic or similar pressure to make the weld. Mr. Rigg's attention has been given to the question of proportioning the consumption of water to the work done. This becomes, of course, more important as the applications increase, and if Mr. Rigg's engine effects this he will prove a good friend to hydraulic transmission. At the same time, while almost impossible to be put in figures, the author sees no reason to modify his often expressed opinion that simplicity and directness of action, although, perhaps, apparently more wasteful of water, yet in the long run these are more conducive to economy than is generally supposed. During the earlier years of his connection with this class of machinery, the difficulties of getting his system adopted at all left him no time for refinements. Later on, when this work became less arduous, the question of improvements in

detail came to the front, and, as Mr. Fielding observed, the question of economising water and the use of high-speed hydraulic motors received great attention, and as regards the latter from no one more than Mr. Fielding himself, and with his remarks on this subject the author fully concurs. Mr. Nursey's wide experience and opportunities of noting any advances in engineering matters give any observations he may make unusual value, and his approval of the various applications of the author's system, whether made by himself or others, is very gratifying. If the American musical instrument referred to by Mr. Halpin does what is claimed for it, the remarks already made by the author, either in his paper or in the discussion, will require reconsideration. But the idea of a perennial stream of water, at 1500 lbs. per square inch, being drawn from an accumulator is one calculated to appal any hydraulic engineer who has to consider the first cost of pumps and accumulator. Of course if the 80 per cent. efficiency is attained, any extra first cost may be justified, but for such quick speed rotary machines it is, except under very special conditions, questionable whether hydraulic pressure is the best. A practical objection to such rotary engines is that workmen will leave them running, even when no work is being done, or the work is being changed. The waste then is, of course, enormous. In reference to cold riveting, the question of flow is all one of "time." The conditions otherwise do not differ from the same action when hot. Rivets of $\frac{3}{4}$ inch diameter have been successfully closed, and the larger ones simply require more power. At the same time it is more than probable in such cases the great pressure necessary would injure the plates. Hence Mr. Halpin's warning deserves careful consideration. In reply to the remarks by Captain Bate, he (Mr. Tweddell) had already referred generally to the question raised by him. There could not be a proper comparison between the different systems of transmission of power unless they knew exactly the character of the work to be done. It was very difficult to say how they were to store, to the best advantage, 120 horse power to be delivered in the space of twenty minutes. Many different considerations entered into the question. Mr. Slater's observations came from one who has just seen the advantage of adopting the author's system, and any improvements must always owe much to those whose suggestions are the outcome of practical experience. The author regretted that more had not been said on the subject of workshop arrangement, and the judicious use of cranes and labour-saving appliances. It is in the liberal use of these that any hope exists of competing with cheaper foreign labour.

Fig. 4.

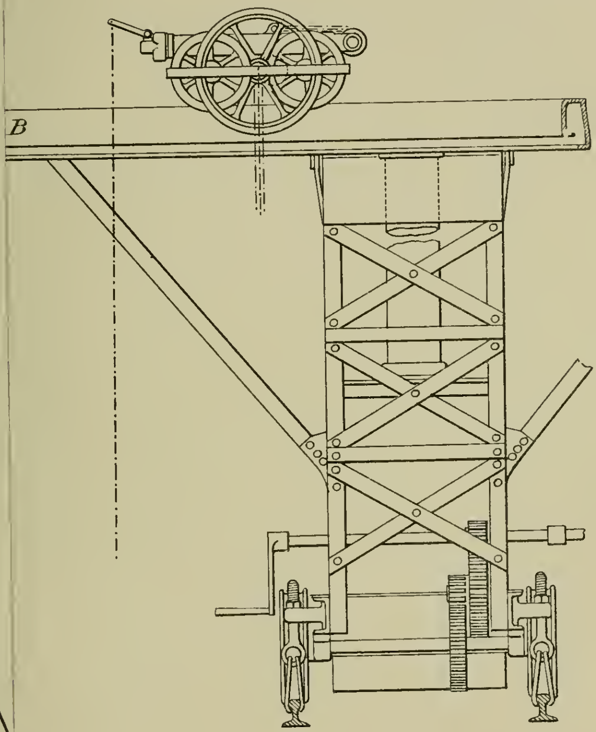


Plate I

Fig. 2.

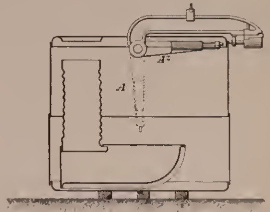
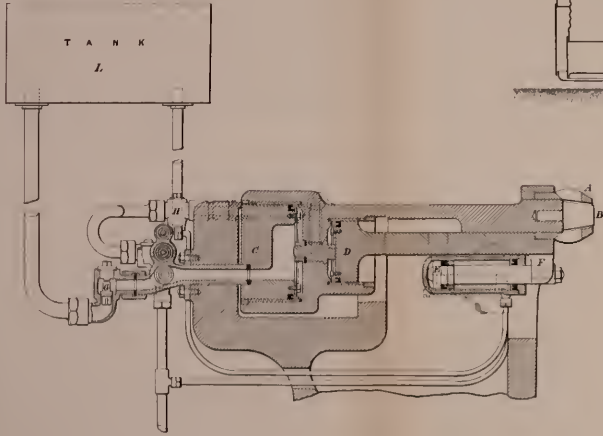


Fig 1



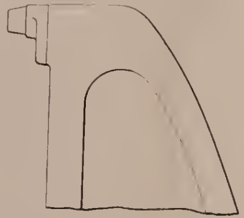


Fig 3

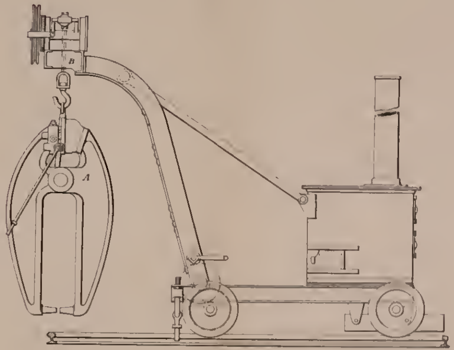


Fig 4

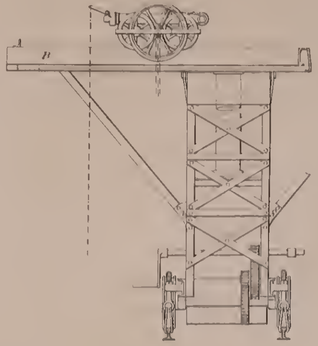
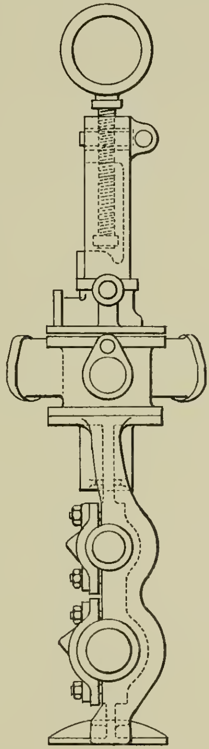


Fig. 9.



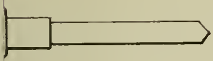
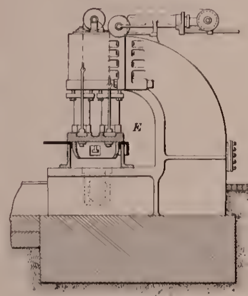
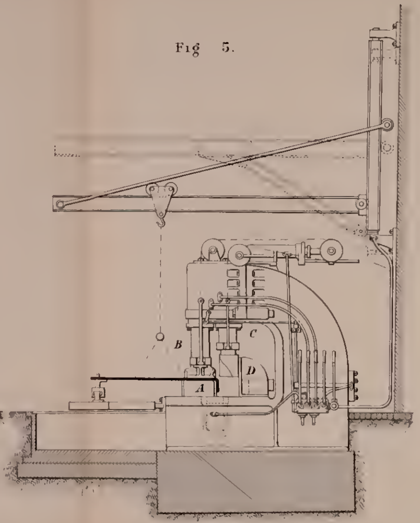


Fig. 6



SIDE ELEVATION SHOWING MACHINE FLANGING FURNACE MOUTHS

Fig. 5.



SIDE ELEVATION SHOWING MACHINE FLANGING BOILER ENDS AND HYDRAULIC CRANE ABOVE

Fig. 7.

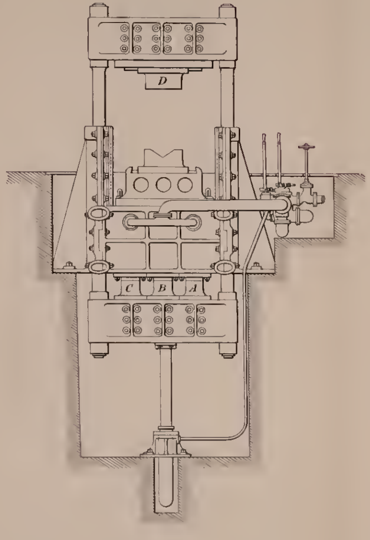


Fig. 8

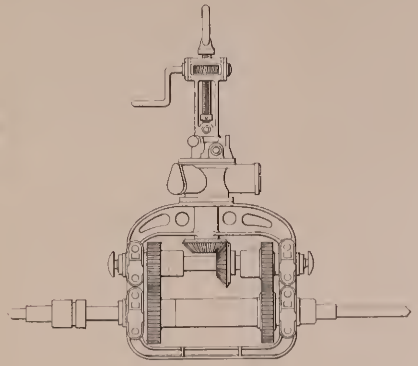


Fig. 9.

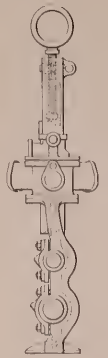


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Fig. 12.

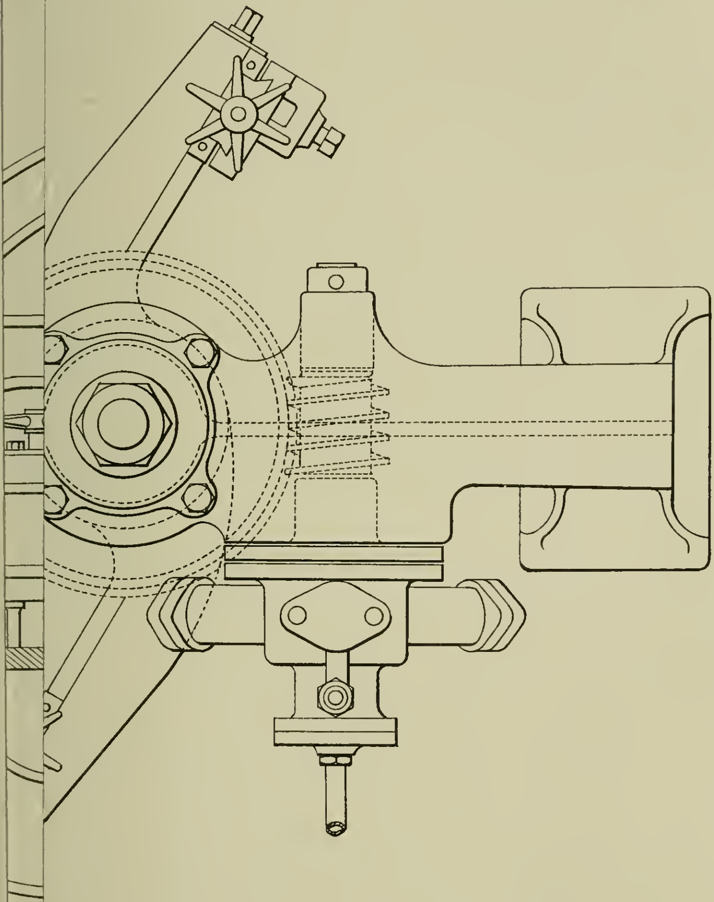

Fig. 10.

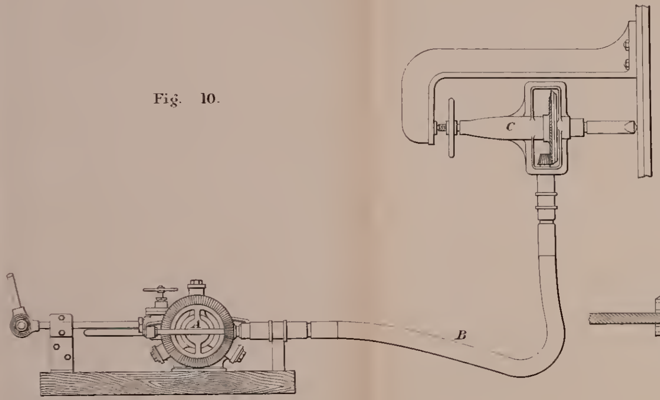

Fig. 11.

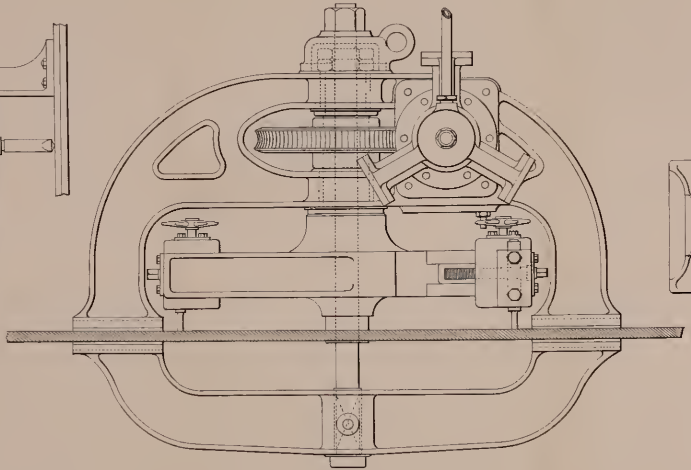

Fig. 12.

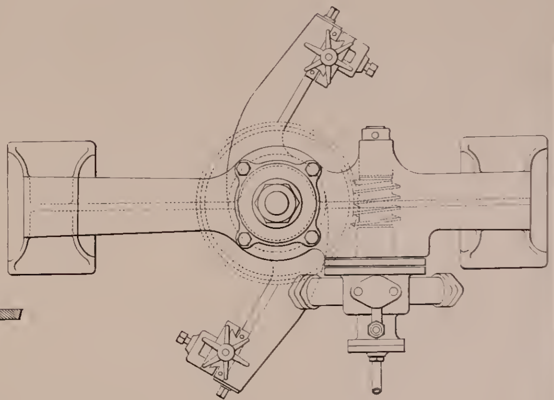

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Fig. 16.

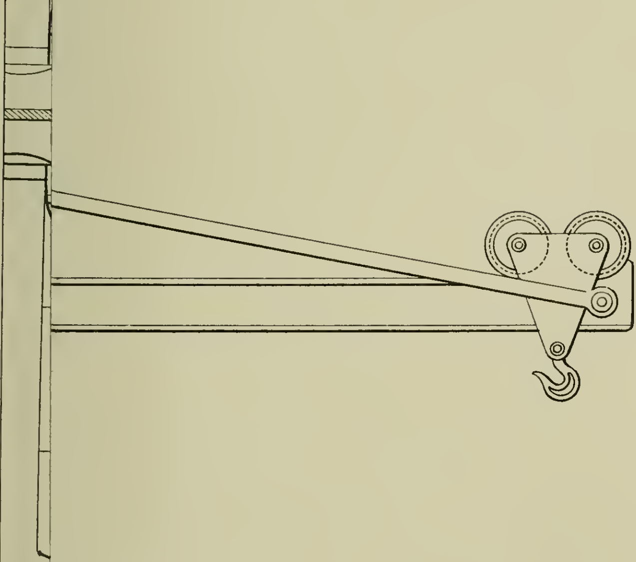


Fig. 13.

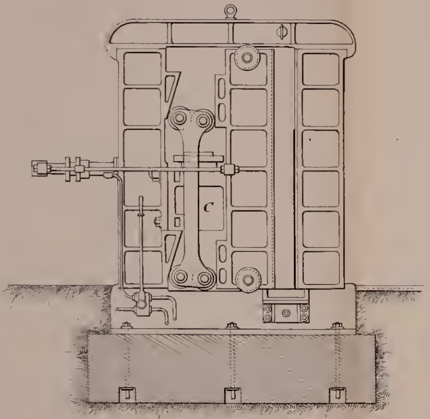


Fig. 14.

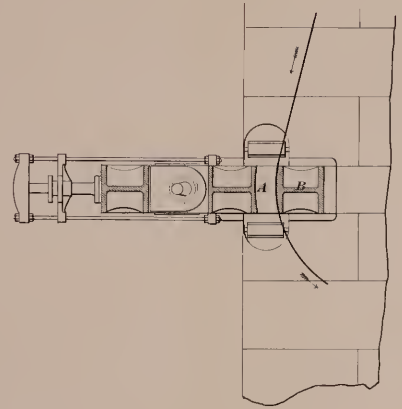


Fig. 15

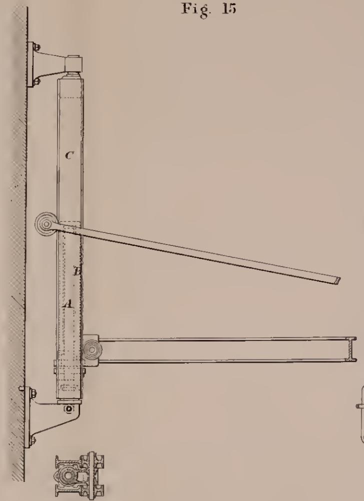
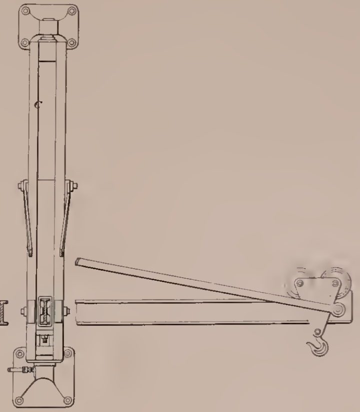


Fig. 16.



E & F N Spon, London & New York

April 14*th*, 1890.

HENRY ADAMS, President, in the Chair.

ON WEIGHING-MACHINERY AND AUTOMATIC APPARATUS IN CONNECTION THEREWITH.

By William Henry Brothers.

The fact that a paper professedly treating of the mechanical features of certain forms of weighing-machinery should be an acceptable contribution to the proceedings at a meeting of the Society of Engineers, is an encouraging omen of the growth of interest in a branch of manufacture claiming to give expression to fixed scientific laws, the fruits whereof find hourly application in transactions of purchase and sale. A widespread familiarity with the principles underlying appliances of such a popular character as those about to be considered might, not unreasonably, be looked for; the anticipation would, however, prove to be illusory. Upon the analytical and assaying balances, scientific instruments of the utmost delicacy of adjustment, approximating to mathematical precision, one or two brief treatises are extant. Also in the various encyclopædias, articles may be found in which the theory of the balance and application of the principles of leverage to the construction of the weighbridge or road weighing-machine are descanted upon; the examples of the latter, cited for the purposes of illustration, being oftimes of an exceedingly primitive type. Apart from these, however, the author has no knowledge of the existence of any technical literature in this country immediately connected with the subject of weighing-machinery. The recent manifestation of interest in appliances of such notable utility in the daily requirements of trade, is, perhaps, even now scarcely due to the peculiar mechanical conditions which they exemplify; but, rather, owing to the circumstance that with the advent of the present year a new Act of Parliament came into force for the better regulation of the system of Weights and Measures Inspection obtaining in this country. The

enactment in question, which is destined to exert a potential influence on the future of weighing-machinery, is beyond doubt the most comprehensive and far-reaching in its provisions, and is likely to prove more efficacious in its application than any similar measure which has previously found a place in the Statute Book. The Legislature has actively occupied itself with the subject at frequent intervals since the days of Magna Charta, although much earlier records survive of statutory intervention, some forty Acts of Parliament more or less closely relating to it remaining unrepealed at the present day. The last few years have witnessed a growing dissatisfaction with the administration of the law as based on the Act of 1878. The object of this Act was "to consolidate (for the purpose of statute law revision), and not to amend, the law," and was further described as "a simple reproduction of the existing statute law in a compact and consistent form, without amending it by the introduction of more effective procedure, or otherwise substantially altering it." Efforts were made during the last three Sessions of Parliament to once more amend the law of Weights and Measures, but it was not until the Session of 1889 that a Bill introduced under the auspices of the Government was carried to a successful issue. This Bill, which in its early stages bore the names of Sir Michael Hicks-Beach and Baron Henry de Worms, was materially altered in its passage through both Houses, in deference to the traditional privileges of local authorities in such matters; but the provisions which remain, and are now in operation, may, if intelligently applied, go far to cause our Weights and Measures Laws to approach to an imperfect comparison with the admirable and well-digested systems prevailing in Germany, France, and other countries of Europe. Former legislation in England on the subject has been remarkable, if for nothing else, for the perpetuation of what can only be fitly characterised as a glaring anachronism. Ever since the State undertook the guardianship of the public interest in this direction, and sought by penal decree to ensure the observance of honest interchange between buyer and seller, it has prescribed the form and material of lawful weights, and provided that after due examination an official stamp of verification should be impressed, in proof of comformity with the Imperial Standards or authenticated copies thereof. Yet, strange to say, the counterpart of the weights, i. e. the balance, without which the former are but shaped pieces of metal, has come in for no such departmental regulation and control. No scientific conditions as regards construction have hitherto attached to the manufacture of weighing-machinery; it has rested with the maker to fashion and construct his wares in the

manner which seemed best to him, and the most likely to attract the purchaser, often by virtue of cheapness or other extrinsic qualities. A new order of things has now happily been entered upon. Every weighing-machine, balance, and steelyard must henceforward bear an official mark of verification, and indications are not wanting that the Board of Trade, through the Standards Department, will urgently recommend to the local authorities the exercise of a wise discretion in the forms of weighing apparatus permissible for use in their several districts, close regard being had to quality of material and propriety of construction. For a number of years past, however, there has been an ever increasing demand for accurate and reliable weighing instruments. The growing and many-sided requirements of trade could not be content with the simple equal-arm balance, or the unequal-arm balance, the steelyard or *Statera* of the Romans. Considerations of time and space, and the economy of labour, imperatively demanded improvements on these old-world models. Hence various adaptations, to special purposes, of the *Libra* and the *Statera*, became an absolute necessity, which the ingenious inventor and the manufacturer set to work to supply. It affords a somewhat curious speculation, that weighing apparatus has never yet, to any practical end, been independent of the levers of mechanics. The torsion balance, which was introduced in America a few years ago, is a bold attempt to supersede the knife-edge fulcrum of respectable antiquity. This invention is hardly yet beyond the experimental stage. It is at all events still on its trial in the United States as a commercial appliance, and the development of so interesting a theory will be watched with interest on both sides of the Atlantic.

The idea of a torsion balance is confessedly a very attractive one. The making of an accurate and symmetrical knife-edge is a primary difficulty in the construction of a good balance. When, however, we remember that assay balances with knife-edge centres can be, and are, made to show indications of the $\frac{1}{10000}$ part of a grain, such a principle is hardly likely to be deposed by a novelty which has not yet undergone the test of time.

The idea of substituting torsion wires for knife-edges in balances was the outcome of experiments by two German savants, Professors Gauss and Weber, connected with the University of Göttingen. A later student of that university, Professor Roeder, who died some two years ago, continued the experiments to a more practical end than had been achieved by his predecessors in this interesting inquiry, and in association with Dr. Alfred Springer, of Cincinnati, effected many improve-

ments in this system. Dr. Springer continued to develop the invention after Professor Roeder's death, and the patents that were taken out as a consequence of their joint efforts are now being actively worked by the Springer Torsion Balance Company, of New York.

The simplest form of torsion balance is a very light beam supported at its middle point, which is also its centre of gravity, by a stretched wire, the wire being firmly fastened to the beam. A weight placed at one end of the beam should exactly balance a weight of similar value placed at the other end. The sensitiveness of such a balance depends, of course, upon having the torsional resistance of the wire almost infinitely small. A very thin wire was accordingly employed, and, as thin wires when stretched horizontally are not strong, such a balance, it was found, could only be used for very small weights. It was in the foregoing manner that a Mr. Richie constructed a torsion balance, which is referred to, but condemned, in the article on the balance in the 'Encyclopædia Britannica' (9th edition).

It must be allowed that Professor Roeder and Dr. Springer have expended a large amount of ingenuity in their endeavour to cope with the effect of the torsional resistance in diminishing the sensitiveness of the balance. They claim to have accomplished their purpose in a number of different ways. The simplest, and the one which it is probable will be generally adopted if their balance should ever receive popular recognition as a weighing instrument, is the placing of the centre of gravity above the point of support. This is the case with certain counter machines of English and foreign manufacture, to which incidental reference will be made in the course of this paper; the parallel motion of the pans being insured by linked stays or subsidary beams having knife-edge connections. In the torsion balance, the top-heaviness which would destroy the equilibrium of an ordinary weighing beam without controlling adjustment, acts in the opposite direction to the torsional resistance of the wire, and may be made to neutralise it. We have thus the torsional resistance exerted to keep the beam horizontal, and the high centre of gravity tending to tip it out of the horizontal. The adjustment of the position of the centre of gravity, so as to neutralise the torsional resistance, is most easily made by having a poise placed immediately above the centre of the torsional wire, and making it adjustable vertically by means of a screw and nut. When the torsional resistance is, by this means, neutralised, the balance becomes extremely sensitive, and any lesser degree of sensitiveness that may be desired can be obtained by simply lowering the poise.

Thus, in modern days, weighing-machinery is to be found in

use of the most diverse construction. A glance at the catalogue of a well-known firm of makers will discover some 20 or 30 types of weighing-machines, each differing in construction from the other in all save the fundamental principles of leverage, and all claiming to be supported by scientific warrant. The scales with which the emblematical figure of Justice is equipped, have developed into a massive even-armed balance with knives working on polished agate planes, and with an arrestment whereby the knives and bearings are disconnected when it is not in use. Such an instrument, with no pretension to the delicacy of an assaying or analytical balance, will carry 56 lbs. in each scale, and readily discover any difference in weight within half a grain. The counter scale, with swinging pans, pendant by chains from an equal-arm beam, is supplemented by the "inverted" balance, in which the pans are placed above the beam, as being a more convenient apparatus for certain purposes of retail trading. In order to ensure the horizontal and parallel motion of the pans in machines of the latter kind, and the harmonious movement of the balance generally, many ingenious arrangements of the under-mechanism, rendered necessary by the alteration in the centre of gravity, are applied. Of these the *Beranger* and *Roberval* systems, largely in use in England as well as on the Continent, are prominent types. So, too, in the case of the steelyard of ancient times, whether intended to be used separately or to form part of the mechanism of a compound lever weighing-machine; the once familiar hanging counterpoise on the arm, and the proportional weights depending from the end of the arm, have given place in the better quality of machines to smoothly sliding counterpoises which suffice to indicate up to the full weighing capacity.

A comparatively small case or framework, containing three levers in connection one above the other, practically a triple steelyard, will, when hung to a crane, weigh a body of 50 tons; the tare and main indications being defined without the employment of loose weights.

The ponderous weighbridge for heavily-laden wagons or other vehicles, with a range of 50 tons weighing capacity, has superseded the cumbersome weighing beam of limited power; and engineers will be familiar with the mighty machine of the former type, by means of which the pressure exerted by each wheel of a locomotive engine can be accurately gauged. In the process of evolution these developments have led in recent years to the introduction into common use of ingeniously conceived inventions for automatically weighing and automatically recording weighings; joint operations to which electricity has at length been successfully applied.

The exercise of inventive skill expended on weighing machinery has hitherto had little recognition or acknowledgment in official quarters. The personage charged with the inspection of weights and measures, who might be an ex-policeman or other superannuated servant of a local corporation, has been the sole arbiter as to whether a "pair of scales," as he would probably generically term all weighing appliances, were in accurate adjustment; and in notorious instances his arbitrary dicta and untrained judgment have had unreasonable weight with the magistracy, his employers. With the scientific conditions underlying any particular apparatus, it has not followed that he should have any acquaintance whatever. Instances are on record of an inspector distinguishing himself by challenging the proportional weights on the steelyard arm of a lever platform machine, and condemning them because they failed to discover the amount of the dead-weight with which they were marked. Not for him to comprehend that, by an arrangement of levers, one pound on the end of the steelyard might counterbalance a pressure of 50 lbs., for example, on the platform. With the operation of the new Act, a sanguine hope may be entertained that this relic of the vestry is now in a fair way of being shelved. The Weights and Measures Act 1889 provides that all persons hereafter appointed to inspectorships shall be required to pass an examination, conducted under the auspices of the Board of Trade, in subjects which include arithmetic, including decimals, elementary mechanics, elementary physics, practical verification of weights and measures and of weighing and measuring instruments.

If to this guarantee of a certain degree of technical knowledge in inspection officers, should be added the official recognition and sanction of such forms of weighing instruments only as will answer to scientific requirements, and not tend to facilitate the commission of fraud, it may be confidently anticipated that weighing-machinery in use in the United Kingdom will eventually come up to a standard of excellence commensurate with the importance of the work it is called upon to perform. Of this, the model regulations lately issued by the Board of Trade, although somewhat elementary and crude, afford earnest of an improved condition, to which all those interested in the theory or manufacture of weighing-machinery must afford a grateful welcome. This is not the place for a dissertation on the politico-economic bearings of the question; otherwise it might be profitable and instructive to consider whether some similar body to the *Normal-Aichungs-Kommission* in Germany might not with advantage be established in this country. On that commission the University Professor of Science and the heads of Technical

Schools naturally take their seats. Its office is to define the various forms of weighing-machines and balances which may be lawfully used for trade in the Prussian territory, and periodically to examine and sit in judgment upon any new invention which it might be sought to import into customary use. Needless to say the weighing apparatus in use in Germany, whatever may be its shortcomings from the artistic point of view, is theoretically sound in construction. The English inventor, manufacturer, and artisan are not behind the Teuton. Many and admirable examples of the scale-maker's craft have been called into existence during the past 50 years by the needs of the State in relation to the construction and verification of the imperial standards. One instrument in particular is remarkable as a combination of theoretical propriety and sterling workmanship. It is an equal-arm balance constructed to the design of Captain Kater in 1812, and used by him for the original verification of the imperial standard bushel. After re-construction, and the addition of certain modern improvements, it is a perfectly reliable instrument at the present day. The beam, 7 feet long, is made of wood; it carries 300 lbs. in each scale pan, and will show any difference in weight within five grains, its sensibility many years ago being considerably greater. This balance, in company with a fine collection of vacuum and other balances, forms part of the equipment of the Standards Department of the Board of Trade.

It has already been observed in the course of this paper that in regard to weighing-machinery inventive effort is chiefly directed towards automatic action, either for weighing or recording weighings made, or a combination of both properties.

The weighing-machine to which was attached for the first time a steelyard having no loose weights, was a noteworthy advance in this direction. The obvious advantage of dispensing with loose weights, which might easily be mislaid or mixed up with the weights of another machine having different leverage proportion, was supplemented by the convenience of being able to see by a glance at the markings of the steelyard the weight indicated by the index nib of the movable slide. But in India, for example, something more than this was needed. Two machines must be employed if Indian, as well as English weight of a given mass, were to be ascertained, unless some further improvement could be effected. To mark a different standard on each side of the steelyard was an easy matter, but the practical use of such an arrangement would be attended with inconvenience; besides, certain of the Indian State Railways required to simultaneously weigh in English, French, and Indian notation. This latter necessity gave rise to the intro-

duction of a revolving bar attached to the steelyard, which might bear as many different standards as it possessed faces, and be firmly locked into position with the requisite standard exposed. In the pattern, of which an illustration is given, Fig. 1, the revolving bar A, usually of gunmetal, takes the place of the indicating plate which bears the graduations of an ordinary steelyard having no loose weights. The main body or blade of the steelyard B carries the heavy poise C; while running parallel with the revolving bar is a bar carrying a small poise for indicating the finer divisions. The nib D on the heavy poise, which falls accurately into the divisions on the revolving bar, is raised by means of a handle and pawl E when it is necessary to transfer it to another division in balancing the load. The entire arrangement is very rapid in action, and is unerringly correct in its indications.

A bare enumeration of the many ingenious contrivances now before the public for automatically weighing and indicating is not possible within the limits of a single paper. The most that can be done on the present occasion will be to make some detailed reference to certain representative inventions of this class. In the illustrations which follow, an acquaintance with the lever mechanism will be taken for granted, and the descriptions will accordingly be confined in the main to those portions of the apparatus whereby the weight is automatically discovered or indicated. Simple mention of the most ancient form of self-indicating weighing-machine, viz. the spring balance, must suffice. The theoretical objections to this system are sufficiently evident and well understood, and no plea of justification for its use as an instrument of precision can be urged on scientific grounds.

The dial-indicating machine, with pendulum connection, is probably the parent type of automatic weighing apparatus. Several adaptations of the principle are to be met with in Germany, but owing to the salutary regulations in relation to weighing-machinery which obtain in that country, are only permitted to be used in a public sense for railway passengers' luggage and for parcels of no declared value. This system is, indeed, open to fatal objections where any approximation to accuracy is essential. In each of the following examples the sustaining levers upon which the platform rests are connected by means of a tension rod with the pendulous lever. The depression of the sustaining levers, due to the pressure of the load on the platform, produces a largely increased inclination of the angle index finger A, as shown in Fig. 2, and the position of the latter on the arc B indicates the weight of the load. It will be evident that the pressure of the connecting rod C on the elbow D of the index finger near to the knife-edge fulcrum

will largely multiply the motion at the point of the needle, and accordingly, unless the arc were so large as to unfit the machine for practical use, it would be impossible to indicate the finer divisions with accuracy, especially when it is noted that in the present instance the scale rises by divisions of 10 kilogs. to 200 kilogs. Nor is this the only consideration which disqualifies the use of a single pointer in machines of other than very limited capacity. The arc must of necessity be circumscribed in compass, as otherwise the knife or centre would lose its sharp edge contact with the bearings. It will be noticed that this condition is but just preserved when the index needle is at the extreme limit of the arc. The maximum radial angle of an arc proceeding from a knife-edge of a given size is strictly defined, as will be seen by the accompanying diagram, Fig. 3. An attempt has been made to remove the objections indicated by affixing a toothed quadrant at the extremity of the index lever, which gears into a toothed wheel carrying a pointer, this pointer marking the indications on a circular dial. But two conditions here arise which are equally fatal to precision. Either the cogs fit accurately, when a great amount of friction is engendered, or they work loosely, with the consequence that back-lash results. The pendulum principle, as applied to platform weighing-machinery, is impracticable in operation, although, curiously, the same principle is successfully applied in the case of, and is indeed always present in, analytical and assaying balances for the purpose of obtaining precise and delicate indications.

The vertical needle of a fine balance is essentially a pendulum, but the movement at its point is derived direct from the arm of the beam, and not through the medium of several fulcra. Accordingly, an almost imperceptible movement of the beam in its delicate poising will cause the point of the index to move $\frac{1}{32}$ of an inch (a common indication), or even a shorter space, which the markings on the scale piece or dial make clearly visible. Results are obtained in this manner which would be impossible by means of weights, and they are requisite, for the assayer expects to read indications from his instrument to the $\frac{1}{10000}$ part of a grain.

The entire distance to be traversed by the point of the needle of the fine balance is so very short as to require but the smallest movement at the end of the arm of the beam to effect a delicate indication, whereas in a platform weighing-machine, the whole of the indications having to be effected by the index needle, the arc has to be of wide extent, which entails extreme contraction of the knife pivot.

In Fig. 4, the change of inclination of the sustaining levers

causes the rising or falling of a perpendicular guiding rod A, the upper and downward movements of which influence the finger of an index plate by means of a tooth rack and pinion, and cause the dial indications. Here, again, the drawbacks of friction and back-lash arise with the same force as in the case of Fig. 2. It would appear that accuracy is impossible of attainment where toothed gearing is employed, otherwise the indicating arrangement, as shown in Fig. 5, appears to be plausibly simple and effective. In this case the steelyard beam has the bottom edge in the form of a toothed rack, into which gears a toothed wheel mounted on bearings in the sliding poise. As the sliding poise is moved along the steelyard until the machine is balanced, the wheel, which has a graduated dial, revolves, and the pointer on the sliding poise indicates the weight when the wheel comes to rest.

The foregoing examples may be regarded as primitive attempts to solve the problem of effective self-indicating weighing-machinery; a problem which may, not improbably, find its solution in the application of mechanical powers, in combination with natural forces of quite a different kind. A consideration of the properties of the pendulum balance is not uninteresting, even in its early imperfect application, inasmuch as it leads to a very notable invention, based on the same principle, which is being extensively used throughout the civilized world. This is the automatic weighing-machine, Fig. 6. invented by *Mr. Percival Everitt*, which confronts the public at railway stations, restaurants, theatres, and elsewhere at home and abroad. The object of this invention is to cause the weight of a body being weighed to be indicated on a dial by the act of placing a coin in the apparatus. The platform upon which the body to be weighed is placed (the invention has hitherto been exclusively applied to the weighing of persons) is suspended by the arrangement of levers and in the manner customary in the case of the ordinary platform machine. The transmitting lever which projects from the platform to the middle of the pillar is attached at its extremity by knife and bearing to a vertical rod joined to a steel ribbon, and is thereby connected with a weighted arm B, projecting from a pivoted spindle C, which forms the counterbalance of the load, and with a weight D which forms the counterbalance of the platform and levers. A cord by which the latter weight is suspended passes round a pulley on the spindle C; the steel ribbon is attached to and wound round a drum upon spindle C, so that when a weight is placed on the platform the ribbon will partly rotate the spindle and pulley, and the weight will be raised and the weighted arm will partly rotate, until the body to be weighed is counter-

balanced. A toothed wheel E is fixed on the spindle C, and serves to operate, when the spindle C is rotated, a pinion F, fixed upon an arbor which carries the index F_1, this index moving round the dial inside the apparatus. A second arbor (independent of the first) to which is attached an indicating finger on the outside dial, and upon which is a pinion G, gears with a pivoted quadrant H provided with a counter-weight I. To this quadrant is attached an arm K which carries the receptacle of box L for the coin, having an open top. The box is normally situated immediately below a shoot M, extending from a slit in the frame of the apparatus. The bottom of the box is provided with a cam N which limits the outlet to a width less than the diameter of the coin, which is necessary in order to operate the mechanism. The shoot is formed with an opening in its bottom of such a size that any coin smaller than the predetermined coin will pass through the said opening into the apparatus without operating the parts. The bottom of the box with its movable cam is kept in a closed position by a counter-weight so long as a person is on the machine, and is opened in the manner hereinafter described. A stop O is provided for regulating the movement of the outer index by coming in contact with the index inside the apparatus. The stop O is fixed on the inner arbor of the index, and when the pinion G is rotated by a coin dropped into a box overbalancing the arm and operating the quadrant H, the stop O will rotate until its projection meets the index F_1 inside the apparatus, when it will be stopped thereby at the proper position to indicate, by means of the outer index, the weight of the body on the platform. When the body is removed from the platform and the weighted arm B, and weight D, resume their normal positions, the index will, in rotating, bear against the stop so as to again raise the box. A catch P is pivoted to the movable bottom of the box in such a manner that when the box is depressed by the weight of the coin therein, the finger or catch P will, by coming in contact with a series of pegs Q, on the frame of the machine, be caused to turn on its pivot and so pass them. When, however, the box is again raised by the removal of the person from the platform, the pivoted catch P will again be brought into contact with the pegs Q on the frame of the machine, but will remain rigid and so cause the cam to withdraw from the bottom of the box and permit of the delivery of the coin into the box provided for the purpose. A cylinder R, containing water or other suitable fluid, into which a piston connected by a rod S to the pulley previously referred to is loosely fitted, serves as a cushion to lessen the shock on the weighted arm and suspended weight

resuming their normal position when the weight is removed from the platform, and as a means of bringing the indicating finger to rest.

Briefly, by means of this ingenious contrivance, if a person places himself on the platform of the machine, the spindle will, by means of the arm rod and steel ribbon, be partly rotated, and the weight will be thereby raised and the arm rotated a certain distance according to the weight of the person on the platform. This movement of rotation will be communicated to the index by means of the quadrant and pinion; the extent of the movement of the inner index being practically that to which the outer index will be subsequently moved to indicate the weight on the dial. If a coin of specified size be now passed through the slit in the case it will pass into the box and by its weight overbalance the arm attached to the quadrant (which carries the box), the arm in falling will, by means of the quadrant and pinion, rotate the stop on the inner end of the arbor, together with the index on the dial, until the projection on the stop comes against the inner index, and the weight of the person on the platform will thereby be indicated on the dial. Upon the person stepping off the platform the weights will resume their normal positions, and the inner index as it is carried back by the mechanism will carry back with it the stop on the inner end of the arbor of the index, the box will be thereby raised, the box will be opened by the finger or catch pivoted to the bottom of it coming against the pegs on the frame, and the coin will be discharged into the bag. If a smaller coin than provided for, should be dropped through the slot it would simply pass through the shoot into the bag; and the slit would of course be of such a size as not to admit of the introduction of a larger coin than was required. Mr. Everitt includes in his ingenious invention for automatic weighing and recording, a ticket-printing arrangement, but, so far as the author knows, it has not yet been applied to the machines with which the public is now so familiar.

An ingenious apparatus on novel lines is the invention of Mr. Eugen Wölner, of Liverpool, Fig. 7. The bottom lever mechanism and the relieving gear have certain original features, but the author's present concern is with the tackle whereby the indications are brought about. The indicating apparatus in the figure is drawn in its half-way position. A pillar A rising from the base-frame of the machine carries by knife-edge a compound lever B, to one arm of which, near the centre of motion, a suspension rod C is connected, whereby the transferred power from the bottom levers is taken up. On one arm, the left in the illustration, is a sliding weight for adjusting

tare. On the same arm, at the extreme end, is a suspension rod D, sustained by knife-edge E and shackle, with a piston in a cylinder filled with liquid (petroleum or other oil, preferably) and covered with a box cover. The piston is made up of a number of plates a little apart from each other, to allow of the liquid forming a hydraulic packing. The cover has a hole in its top and bottom large enough for the suspension rod to pass through, plus clearance, and is made in the form of a box in order that the fluid in the cover may act like a cushion for the fluid that tries to rush up through the bottom hole; and also for the purpose of hindering the motion of the liquid in the plunge box by the working of the piston. The other arm of the compound lever on the opposite side has a counterbalance weight by which the indicating apparatus is brought to zero; and is also provided with a knife-edge F fixed at the same distance from the centre that the knife-edge on the opposite arm is. From this knife-edge F is also suspended a shackle and suspension rod with a piston in a plunge box. The latter is filled with fluid and covered with a box cover, and is in every respect like its fellow plunge box. The one piston in its plunge box checks undue oscillation of the compound lever in its upward movement, and the other piston in its plunge box acts in a similar manner for the downward movement. The arms provided with knife-edges constitute the equal beam of the compound lever. To ensure the same level of the fluid in the two plunge boxes, they are provided with a tube, with a cock fixed on the side near to the bottom of the two plungers; thus, when the fluid is poured into one plunger, the cock is opened and the liquid finds its own level through the tube. The communication is then disconnected if desired by turning the cock. The liquid in the plunge boxes may be at high or low level without having any interfering effect upon the counterpoise weight suspended from the end of another arm G of the compound lever going in a downward direction. This arm G constitutes the pendulous lever. An arm H going in an upward direction and bolted to the compound lever, carries the dial on which are a series of scales for the minor weights, and, on its top edge, a scale for the major weights. The indication on the dial takes place in the following manner:—On one arm of the compound lever is bolted a segment quadrant I, on which is fastened a chain that passes round a helical grooved pulley working in a bracket K fixed on a carrier frame L which is bolted on the base frame. The chain is fastened on the middle of the pulley to prevent it slipping, and a weight M at the other end keeps the chain tight. On the inner pivot of the pulley is fixed a pointer wheel that points to the scale for the minor weights on

F 2

the dial, and a pointer that is fixed on the casing of the apparatus points to the scale for the major weights on the edge of the dial.

To make the operation of this indicating mechanism quite clear, assuming the machine to be at zero, the needle fixed in the top of the framework will cover the first numeral on the scale which runs along the top of the dial, representing, for example, hundredweights; while one of the four revolving fingers will be directed towards the first numeral at the foot of the first line of the vertical graduations, which may represent pounds or their subdivisions. A pressure on the platform of the machine will depress the left arm of the equal beam of the compound lever, which will cause the dial to travel from right to left, and will at the same time cause the pointer wheel to revolve in the same direction. One finger of the pointer wheel having covered the first line of the vertical graduations, and passed away, will be the signal for a second finger to begin with the first figure of the second line, and so on until the weight on the platform is balanced; the position of the fixed pointer in relation to the horizontal graduations will indicate the hundredweights, while a finger of the pointer wheel will rest at the pounds or fractions thereof on the vertical scale.

It is necessary for the purposes of illustration that the whole of the mechanism should be exposed, but in practice this would not be so. A frame of woodwork would encase the upper mechanism and merely disclose through a slit or window the pointers and so much of the dial as is necessary for discovering the weight ascertained by the machine.

This very interesting invention, and the withal simple mechanism for effecting the indications, goes far to meet some of the objections which prove fatal to other pendulum weighing-machines. The division of labour, as it were, between the dial, the pointer wheel, and the fixed pointer, together with the ingenious arrangement of the scales on the dial, enable as fine weighings to be ascertained as are ever likely to be required from a machine of this calibre. There are the drawbacks of slight back-lash of the chain, and a slight amount of friction in turning the spindle which carries the fingers. The author believes this invention has never been applied to practical use.

One final example of a dial-indicating weighing-machine in which the pendulum is employed, will conclude this branch of the subject in the present paper.

Messrs. Pooley and Son patented, in 1888, a dial-indicating machine for weighing passengers' luggage and recording the frequently attendant excess weights and tare, Fig. 8.

In this invention the steelyard is connected with the platform

in the usual way. The steelyard may be of triple form so arranged that three sets of weights are controlled or worked upon it. One of these is the main-loading weight, one a "tare" for a barrow or other vehicle, and the third is a differential allowance weight. The vehicle tare-weight, slides in connection with a bar, bearing the required graduations, whilst the differential allowance weight slides in connection with a bar graduated in such a manner that the weight may be removed to and set at certain points corresponding with the allowance of weight stipulated for passengers' luggage for first, second, or third class, or any of them; and also for the allowance of weight stipulated for passengers' luggage having different allowances, such as for commercial travellers, these being divided into first, second, or third, or any of them.

In weighing, the tare of the barrow or other carriage, and the allowance for either the ordinary or other passenger being set on their respective scales and at the proper points, the pointer will not move unless the weight exceeds the allowance, but if it exceeds the allowance the pointer will be moved and indicate the extra weight of the luggage; and if the dial be a mileage rate one, and marked with the charges for extra or excess luggage, the pointer will indicate at once the total charge for the excess luggage.

The dial is of circular form set in a frame. The pointer is worked by the movement of the steelyard by means of a chain or cord connected with a segment quadrant on the steelyard. The main weight consists of a body suspended from the steelyard working in water, and so arranged that as more or less weight comes upon the machine the body will be more or less raised out of, or immersed in the water. The body is preferably of annular formation and open at the bottom, having at the top an adjustable air valve or aperture by which air is drawn in and pressed out of the space between the roof of the body and the surface of the water as it is moved up and down. This arrangement is intended to cause the weighing to be effected very steadily and quickly, and the pointer to come to rest without any material vibration. Stops are provided in connection with the machine, so that the movements of the steelyard may be kept within proper limits.

In the Pooley machine the fluid is the weighing element, in contradistinction to the Wölner machine, where it is only present for the purpose of ensuring the steady action of the indicating mechanism. It must not be forgotten that the specific gravity of the water will vary with the temperature, and provision be needed for keeping the water at a uniform level. Added to this drawback is the inconvenience of gearing, which cannot fail to

produce friction to the detriment of the weighing properties of the machine, as instanced in preceding illustrations.

It may not be necessary to do more in a paper addressed to a professional audience than briefly allude to another important invention of recent date in connection with weighing-machinery, inasmuch as an exhaustive description of its complex mechanism, accompanied by drawings and diagrams, appeared in *Engineering* on the 21st June, 1889, and is there available for reference by such as may be interested.

The Snelgrove electric weighing machine, which made its first appearance at the Paris Exhibition of last year, at the stand of Messrs. Avery, of Birmingham, by whom it was manufactured, excited considerable interest. For its construction is claimed a combination of the precision and durability of the compound lever and knife-edge fulcrum machine, with the advantages attaching to the self-indicating properties of the pendulum and spring balances; and, so far, its pretensions have been unchallenged. The whole of the mechanism for balancing the machine and indicating the weights is confined to the steelyard or beam, which may be applied to any description of platform machine or weighbridge, and will accommodate itself to any degree of weighing capacity. The centre action of this unique apparatus is automatic. With any load on the platform the poise or poises will not come to rest until they have attained the exact positions on the steelyard that enable them to balance the load. The machine thus automatically insists on a perfect equilibrium before its revolving indicating dials will stop permanently at any group of figures. Inclosed in a suitable case, with the dial alone exposed, it has the appearance of exercising something akin to human intelligence. When the pressure of the load is felt, the figures are seen to revolve in an agitated manner, and quickly to come to an apparent settlement. Then, for the space of a few seconds, one figure after another is tried and discarded until, eventually, the figures repose in line, and the weight of the load is indicated. An automatic shutter has lately been added, which does not fall until the figures are at rest.

Careful consideration appears to have been given to every important point in designing the Snelgrove weighing-machine. The whole of the electro-magnetic mechanism is attached to the steelyard itself, which is as free to vibrate and oscillate as one of the ordinary pattern. Further, the mechanism is so arranged that no revolving or reciprocating parts when in motion can cause fluctuation of the centre of gravity or balance of the steelyard. A multiple arrangement of poises (without which fine indications would be impossible in a steelyard of

any reasonable length), requires that the large poises shall only come to rest at predetermined points; because the slightest variation in the resting point would cause a serious error on the platform. It is practically impossible with any system of direct gearing to carry the poise out and stop it with any such exactness. Absolute accuracy is, however, obtained by insuring the slight over-running of the poises, and the return of them and stoppage at predetermined points by the elastic power of the helical return springs.

The electric current required to operate the machine is supplied by a small constant battery concealed in the base. For the usual intermittent work on an ordinary weighbridge large Leclanche cells have been found satisfactory. These electric connections and current switches require no attention or manipulation whatever, as they are automatically controlled by the machine itself. On placing the goods to be weighed upon the platform the machine itself closes the electric circuit, and thus obtains the current necessary to operate its mechanism. The attendant, therefore, beyond placing the goods upon the platform, does not interfere with the machine; the entire cycle of operations, switching on the current, balancing the machine, indicating the discovered weight in a single group of figures, returning the mechanism to zero when the goods are removed, and finally switching off the current when the weighing is finished, to prevent waste, being completely performed by the machine itself.

The complicated nature of the mechanism in no degree impairs the sensitiveness or the accuracy of this machine. A prominent and very valuable feature in the construction is the group of large figures—of equal size for major and minor weights—which are displayed in line in so conspicuous a manner as not to admit of being mistaken or misunderstood.

The dial-indicating weighing-machines which have now been passed in review have claimed to do no more than merely indicate the weight discovered by the machine. The noting of the indications so made has rested with the person or persons conducting the weighing operation, and this has led to a demand for further improvements in weighing mechanism. The weighing of goods on ordinary weighing machines often gives rise to errors because the weight has to be read off directly from the beam, without any mark being preserved by which it can be verified; in fact, a verification can only be obtained by weighing a second time. This disadvantage would be remedied if at the time of weighing a printed record produced mechanically on the machine itself could be obtained.

There are, however, two inventions for printing the weight on a ticket or ribbon at the moment of weighing, by the machine itself, which are extensively in use, and have won the public approval and confidence; but at present they are not associated with any automatic action for weighing or recording, being merely applied to steelyards dispensing with loose weights and having sliding poises instead. To the ingenuity of M. Augustin Chameroy, of Paris, and Herr Carl Schenck, of Darmstadt, the credit is due for appliances which have been found of exceeding value to English traders in the United Kingdom and elsewhere under British rule.

M. Chameroy's invention, Fig. 9, as applied to platform weighing-machines consists of a flat steel or brass bar, fixed to the underside of the steelyard, engraved in relief with figures corresponding with those on the exposed face of the steelyard, and representing the graduations of a particular standard. The movable weight slides on this bar and on the beam, and carries below the bar a small plate upon which a ticket rests. Below the plate is a cam, the axis of which is provided with a handle. The operation of this mechanism proceeds as follows:—The goods to be weighed having been placed on the platform, the movable weight is shifted on the beam until a true balance has been obtained. The weight can then be read off in the usual way from the indications on the beam. Then, in order to obtain a printed indication of the weight, a ticket is slipped under the engraved bar, the cam is turned by means of its handle, so as to lift the small plate, and the ticket is thus caused by pressure to receive an impression of the figures corresponding to the weight. The cam handle is then lowered, and the ticket withdrawn. When the weighing has been effected, any movement of the beam is prevented by a hinged stop.

In the diagram, C is the movable beam; D the part connecting the beam with the movement of the platform; G is a flat steel or brass bar fixed to the under side of the beam, and engraved in relief with the figures indicating the graduations of the standard; H is a movable weight which slides on the beam and carries below the bar a small plate J, on which the ticket rests; below the plate is a cam K, the axis of which is provided with a handle L.

Messrs. Avery, who possess the patent rights of M. Chameroy's invention for Great Britain and the British possessions, have added several improvements to it. Among other things they construct the machine with all the printing mechanism contained in the pillar, and so avoid torsion of the steelyard arm,

which was apt to occur in manipulating the handle on the sliding poise, in order to impress the weight on a ticket. The bar with raised figures is attached to the poises and travels with them, instead of being attached to the steelyard. In lieu of tickets a coil of paper may be substituted, which passes over the figures and enables a continuous record of the weighings to be taken without removing the paper.

Herr Schenck's printing steelyard, Fig. 10, although an exceedingly clever invention, lacks the simplicity of M. Chameroy's, of which it is an adaptation. It is encumbered with an amount of gearing, which makes friction and back-lash inevitable. The accompanying illustration of the principal slide will probably serve to make a description of this invention intelligible. A, the principal sliding poise, slides on the steelyard, a section of which is shown at B. Inside the sliding poise is an arrangement of cypher discs and toothed wheels, which act automatically when the slide is moved. The cypher discs S_1 and S_2 have the numbers 0 to 9, the number of cypher discs depending upon the extent of the scale, which in this instance is comprised in the association of three figures. The cypher disc which registers the units S_1 is connected with a toothed wheel Z_1 on a common axis, and geared into a rack I_1. This rack is fixed upon L, which rests in the principal slide, and is therefore carried by it. The motion of slide L within slide A revolves the toothed wheel Z_1, and consequently the cypher disc S_1. In the same way the cypher disc S_2, registering the tens, is connected with the toothed wheel Z_2, which gears into a rack I_2 fixed upon the steelyard B. The movement of slide A along steelyard B revolves the tooth wheel Z_2, and consequently the cypher disc S_2. The third cypher disc representing hundreds, is turned by gearing one division for every complete revolution described by the second cypher disc. Should the slide have four cypher discs, the first and third are moved by the rack, and the second and fourth by a transfer of one-tenth from the first and third. The cyphers or numbers of the discs are in relief on small hardened steel blocks in order to make an impression on the ticket. The cardboard ticket is inserted in the slot T, and is brought up to the figures by the pressure plate P, operated by the cam C.

Two essential conditions are fulfilled by the foregoing ticket-printing arrangements; the centre of gravity of the machine is not displaced by the operation of the slides, and, therefore, the exactness of the weighing is not interfered with by the registration, and the reading of the weighing can be seen on the steelyard, as though no special printing apparatus were present.

An American invention, Clawson's Patent, applied in different ways to automatic weighing and package-filling of granular or pulverised material, is being worked in this country by Messrs. Avery, who have added improvements, and may merit a few words of description. The balance of the machine consists of a beam which has an adjustable sliding weight. A hopper is provided to receive the granular or powdered substance. A rod, which is connected by one end with the beam, has at its other end a dividing knife, which passes into the base of the hopper and cuts off the flow when the weighted end of the beam is counterbalanced, and withdraws when the weighted arm falls again. The hopper is, for example, filled with rice, the weight of the beam is adjusted at one pound. A packet is placed under a spout connected with the hopper, and the operation of weighing and filling begins. As soon as the weight is reached by the passage of the substance through the hopper, the supply is cut off. By the mere act of removing the filled packet from the scale-plate of the machine, the weighing and filling operations are automatically repeated, and so on, until the contents of the hopper are exhausted. In place of weighing the package and product together, three revolving hoppers, A B C, may be used, Fig. 11, which discharge their weighed contents into packets held to receive them. While one hopper is being emptied the one immediately preceding it is being filled, thus effecting an economy in time. These are the hand machines. The same principle is applied to a circular revolving table, having four beams and as many shoots from one main hopper. The machine is worked by power, and the mechanism provides for feeding the machine through a channel with empty cases, and the return of the same when filled in a similar manner. One person suffices to attend to the weighing and filling, and, these operations performed, nothing remains to be done but close up the tops of the cases.

Another machine on the same principle is intended exclusively for the weighing of tea, which will not run freely through a hopper without being stirred or agitated in some way. This assistance is provided by the motive power, the machine is not intended to weigh by hand. In place of the dividing knife in the first example, a catch is substituted, which tilts the mouth of the hopper from side to side as the substance weighed causes the weight of the beam to rise. The attendant has nothing to do but withdraw the filled packages and replace them by empty cases; the weighing and filling operations proceed automatically until the hopper is empty or the motive power is disconnected.

Messrs. Avery have adapted the principle of the Clawson

machine to a machine for automatically weighing gunpowder, filling cartridge cases therewith, and then finally wadding them; the entire cycle of these operations being performed by a single revolution of the machine, which may be driven by an electric motor. The machine as at present made is of moderate capacity, limiting the output to 100 cartridges loaded and wadded per minute. This speed, however, is capable of being largely increased by the simple multiplication of shoots, weighing beams, &c. The machine is fed with gunpowder from a hopper, at the back of which are shoots to receive the cartridge cases. The powder passes from the hopper through small shoots into buckets attached to the ends of a series of small and delicately balanced weigh beams, which fall and automatically close the apertures of the shoots when a given charge has been received. The rows of cartridge cases then advance towards the buckets, by contact with which they release the gunpowder which falls into them. The ends of the beams thus lightened return to their former position and receive a new charge of powder. The filled cartridge-cases next move forward to the rammers which automatically cut out and press home the wads, and, after receiving this operation fall into a cylinder, which, slowly revolving, deposits them six at a time in a perforated tray. A series of three trays are provided which are so connected with each other that each follows the other without interruption to the working of the machine. If a tray does not receive its complement of cartridges, an ingenious arrangement of the mechanism causes the tilt to be thrown off and the machine stopped. The perforated trays can be made to accommodate any quantity of cartridges. The number in each tray being known, a saving of time is effected in counting the cartridges and stowing them away. The weigh beams are adjustable at will to the required charge of gunpowder, whether for military or sporting purposes.

An automatic grain weighing machine, Fig. 12, which at the same time registers the quantities weighed, is used by millers and others having to deal with granular or pulverous substances in large quantities. For example, the grain is supplied through a shoot or hopper, from an upper floor. At the junction of the supply hopper and weighing hopper a pressure plate is fixed which regulates the supply of grain to the weighing hopper. The latter is divided into two compartments, the upper part of this division being fitted with a rocking plate which diverts the stream of grain from one compartment to the other alternately and works simultaneously the outlet doors. When the weighing hopper has received within a small quantity of the

weight required, a knife automatically reduces the flow to a thin stream which continues until the predetermined weight is reached. The compartment into which the stream of grain is flowing is always closed until opened by the action of the beam, which allows of the full quantity contained in the compartment being discharged. The discharge of the grain permits the counterbalanced end of the beam to fall, thereby opening the inlet and allowing a full flow of grain to pour into the other division of the hopper. This action continues as long as grain continues to be supplied to the machine.

The apparatus consists mainly of a double-armed lever or beam A, to ensure parallel motion, carrying at one end B a receptacle C for receiving the substance to be weighed, and at the other end either a constant weight or a scale-pan D for receiving varying weights; secondly, of a feed mechanism which allows exactly as much of the material to flow into the receptacle C as corresponds to a predetermined weight, and then cuts off the supply; and, after renewal of the charge, opens the supply again; lastly, of a mechanism for discharging the receptacle when filled. Above the receptacle C is fixed a hopper or shoot through which the grain is supplied, the spout of which has a brush edge F. The upper part of the rod carrying the weights has a lever G carrying at its end a knife H directed towards the brush opening of the filling hopper. The effect of the grain running into the hopper causes the raising of the weights, more or less quickly, as the stream is rapid or slow. This influence is communicated through the lever to the knife which almost covers the brush opening when the greater part of the charge has been received in the weighing hopper, and allows the remainder of the charge to trickle slowly through. The stream of grain is diverted into one or other of the two compartments of the weighing hopper by means of a swinging flap, which, as before mentioned, is connected with the outlet doors. The outlet doors are kept closed by a bolt which is momentarily withdrawn by the weighing hopper in its descent when it has received its quantum, with the consequence that one door is opened, the swinging flap is turned to the other side, and the other door is closed to await the next descent of the hopper with another load. To a machine of this description, manufactured by Messrs. Avery, is applied a "momentum checker." The sudden influx of the grain when the weighings are at all rapid would by the momentum, added to the weight of grain, destroy the equilibrium of the beam, i. e. cause it to pitch. Accordingly a bolt is shot as the hopper is depressed and prevents the weighted end of the beam from rising for the space of a moment,

thus allowing the machine to settle until the fine stream of grain makes up the quantity for which the apparatus is set. The bolt is then automatically withdrawn by a weight controlled by a train of wheels.

Fig. 13 is reproduced from a treatise on statics published at Leipzig early last century. It represents a balance for determining specific gravity, and is of interest only as suggesting an early anticipation of the fundamental principle of the invention shown in Fig. 8.

In bringing to a conclusion this imperfect dissertation on automatic weighing-machinery, the author is conscious of having done but scant justice to his subject. To give anything approaching a comprehensive survey of such appliances, consistently with adequate treatment of each example, is impossible within the limits of a single paper. Time has necessitated the curtailment of many of the descriptions, and has consequently interfered with the presentation of some of the chosen subjects in their most attractive and interesting light. So much, however, as is intelligible in the preceding pages, may serve to show that the subject is not without interest, and that engineers and inventors may find scope for their ingenuity in the creation of weighing appliances, which, while not sacrificing accuracy, shall possess automatic properties specially fitting them for use in the rapid times in which we live.

DISCUSSION.

The President said that this was the first paper upon the subject of weighing-machinery which had been read before the society. He took this as an indication that few persons were competent to deal with it in the able manner in which it had been dealt with by the author. The paper showed great industry, and an intimate knowledge of the various mechanisms. Economical and rapid means of gauging weights were greatly to be desired, considering the enormous amount of ship, van, and railway traffic which had to be weighed. As an instance of weighing apparatus, which perhaps were not very well known to the public, he might mention the steelyard weighing cranes which had been designed by their honorary member, Lord Armstrong. Twenty-one of these machines, which were in his (the President's) charge, weighed annually an average of two million tons of coal during its transport from ship to barge. Thirty-six similar cranes came occasionally under his notice; and at the present time he was putting up ten other cranes with automatic weighing apparatus of a new form brought out also by Lord Armstrong's firm. Though these matters did not

come much before the public, they were of great importance, and affected many large industries.

On the motion of the President a vote of thanks to Mr. Brothers for his paper was unanimously passed.

Mr. H. I. Chaney said that, so far as he was aware, this was the first paper on automatic weighing-machinery which had been read before any engineering society in this country, though in Germany there had been issued many excellent treatises on the subject. He had hoped that they might have received some information with reference to platform weighing-machines and public weighbridges, such as those commonly used, and on the use and theory of which little had been hitherto published; perhaps the author might deal with them on some future occasion. The more elaborate forms of weighing appliances which were represented by the author that evening had not yet come into general public use. So far as the official testings of the platform weighing-machines and public weighbridges were concerned, there was really little to be done by the testing officers. The duty of the inspector was a practical one, and it was not to be expected at present that he should understand the theory of every weighing instrument brought before him. As, however, trade and science advanced, it would be desirable that the inspectors should understand how to test accurately machines of every form, such as the instruments which had been explained that evening. He had no doubt that within a few years there would be introduced a far more accurate machine for estimating or measuring force than the present heavy cumbersome form of weighbridge. It was curious that there was one simple form of weighing instrument which for thousands of years had undergone little change, and that was the common scale-beam. If they could believe what they read, the scale-beam was a form of instrument which Abraham used; and it was found marked on the monuments of the Pharaohs. The common scale-beam had undergone no change in principle for thousands of years; and all that had been modified was to reduce friction, by means of knife edges, and perhaps to reduce the weight of the beam itself. The weighing bridge, and particularly the automatic machine, was, however, the production of modern times; the earliest weighbridge dated, he believed, from about the year 1710, and the automatic machine was the production of the last quarter of a century only. There was no doubt that in the next quarter of a century a far greater advance would be made; therefore it would become those who had to take official cognizance of such matters to see that they themselves, and the local officers with

whom they might have to co-operate, became fully acquainted with the most modern improvements. It was pleasant to know that there were present to-night so many persons who might have to put into practical operation what the author had put before the meeting. The author remarked on the crude condition of the regulations issued by the Board of Trade. He (Mr. Chaney) believed, however, that all official regulations were necessarily more or less crude. Those who introduced such regulations had to study the demands of the public at large. If they attempted to force ideas on local or other authorities, without leaving local inspectors an atom of discretion, as was done in Germany, France, and Italy, they might fail to carry out any act relating to weighing-machines. In this country invention would not be assisted by a system of central control, such as was carried out at the *Normal-Aichungs Kommission* at Berlin. The English authorities were prepared to consider any proposals with regard to regulations as to modes of testing automatic machines; and he hoped that it would be fully understood that they had not just at present put forward what they believed to be the most precise methods of testing the different forms of weighing appliances, but only what they thought would be best adapted to meet the present practical requirements of everyday life. With regard to the purely scientific side of weighing appliances, there was room for inquiry and report. Upon an investigation, for instance, of weighing-machines of different sizes, it would be found that they appeared to follow no general law as to friction, weight, &c., and consequently it was almost impracticable to require that every kind of weighing machine should weigh accurately to a given amount, as to, say, one two-thousandth part of the quantity weighed. Although in consequence of faults in construction, or a want of information as to correct principles, they could not apply such a rule to compound lever machines, it might be applied to equal-armed weighing instruments, such as scale beams, and to some of the forms of automatic machines explained that evening. He hoped that on these scientific points the author might hereafter be able to give his valuable attention.

Mr. W. N. Colan said that he had no practical knowledge of weighing-machine mechanism. He had no idea that there was so much scope in the construction of such machines for the engineer to apply his knowledge. The cog-rack arrangement in diagrams 4 and 5 seemed to be an arrangement which might very easily, after a little wear, get out of order. The other arrangement seemed to be extremely intricate and ingenious.

Mr. Arthur Rigg said that he had not known that there was so much mechanical design in weighing-machines as the author had brought forward. He admired the extreme ingenuity which had been shown, especially in the construction of automatic machines; indeed one of them, Fig. 7, seemed to be able to do everything but speak. Then the arrangement for using a double scale struck one as an attempted advance upon everything else; only one could not feel quite sure how the chain movement proposed would conduce to accuracy.

Mr. Brothers: That is the defect.

Mr. Rigg said that he supposed that extreme accuracy was not needed in this particular machine, but as regarded the whole subject it was one well deserving to be further studied before a definite conclusion could be arrived at.

Mr. A. P. Trotter said that he had come to the meeting to learn something about spring balances. It was well known that these instruments were liable to errors due to temperature and permanent set and fatigue, but he had not been able to find any definite information about these errors or the means which might be taken to avoid or correct them. He hoped the author would give some such information in his reply.

Mr. E. Horton said that he was very pleased to have heard the author's interesting paper. The various improvements which had been made during the last 25 years had opened up a field for many inquiring minds, but he believed that there were very few firms in the country which had taken the matter up. With few exceptions, the firm of Messrs. W. and T. Avery had been, he believed, the foremost to bring forward many varieties of automatic weighing-machines. He was not acquainted with all the forms of machines shown on the diagrams, but they indicated considerable inventive powers, and would be valuable to persons who wanted to study the matter. As to spring balances, there was nothing better or quicker for weighing parcels in railway traffic, where they were rushed into railway stations the last thing at night. With proper care in construction and supervision, spring balances serve sufficiently well for purposes of that description. But for weighing in the market-place, and for purchase of goods over the counter, they were not sufficiently reliable. Before a machine was condemned, the purpose for which it was intended should be considered, and discretion must be given to the various inspectors to deal with them accordingly. He found that inspectors did not condemn them needlessly.

Mr. Brothers, in replying to the discussion, said that the subject of the paper he had read, namely, "Automatic Weighing

Machines," had been suggested to him by the President, who did him the honour of soliciting a paper at his hands, and for that reason he bad only attempted to deal with weighing apparatus of that particular kind. The subject was a broad one, and when opportunity served it might be competent for him to treat of the platform weighing machines and public weighbridges, and other of the more familiar types of weighing apparatus, to which allusion had been made by Mr. Chaney. He regarded it as inopportune to discuss the merits or demerits of the spring balance on the present occasion. He had never condemned it as an instrument of no utility; on the contrary, he agreed with one of the speakers that spring balances were extremely useful for the hurried work which they were occasionally called upon to perform, and where extreme accuracy was not essential; but, as he had already said that evening, he held that no plea of justification for the use of spring balances could be advanced on scientific grounds, and he should be prepared to support that contention at a suitable time. There were serious objections to be taken to certain of the automatic machines which were illustrated in the diagrams. In the case of one of them, a speaker had pointed out that the gearing was objectionable. He (Mr. Brothers) knew that full well. He had selected the present examples mainly with the view of serving to illustrate what might be termed the evolution of weighing-machinery from the simple balance to the ingenious modern inventions which, as one speaker had observed, appeared to be able to do almost anything except speak. He considered that certain of the machines illustrated were noteworthy achievements in the direction of automatic weighing-machinery. The theory of the pendulum balance seemed to him to possess a certain value, not forgetting that instruments so constructed were not intended for assaying purposes, or for weighing by the grain, but only for the rapid weighing of comparatively heavy bodies. There was, of course, the disadvantage of gearing, and the consequent friction which unfitted them for precise operations. He regarded a perfect automatic weighing machine as yet a thing of the future. Mr. Chaney had commented upon the great progress which had been made in the last 25 years; but he (Mr. Brothers) thought that the next quarter of a century, or even a shorter period, would bring about something like a revolution in weighing machinery, and the examples he had been able to adduce really gave an earnest that such would be the case. Truly, there was nothing new under the sun. The other day he saw some steelyards engraved with the name of the Roman Emperor Augustus, the year of his reign, and the weighing capacity of the instru-

ments. This was going back some 1800 years for a precedent which in one particular at least was first adopted in England by the Government of to-day. It had been a great pleasure to him (Mr. Brothers) to prepare the paper for the society, and he begged to thank the meeting for the courteous and attentive hearing which had been given him.

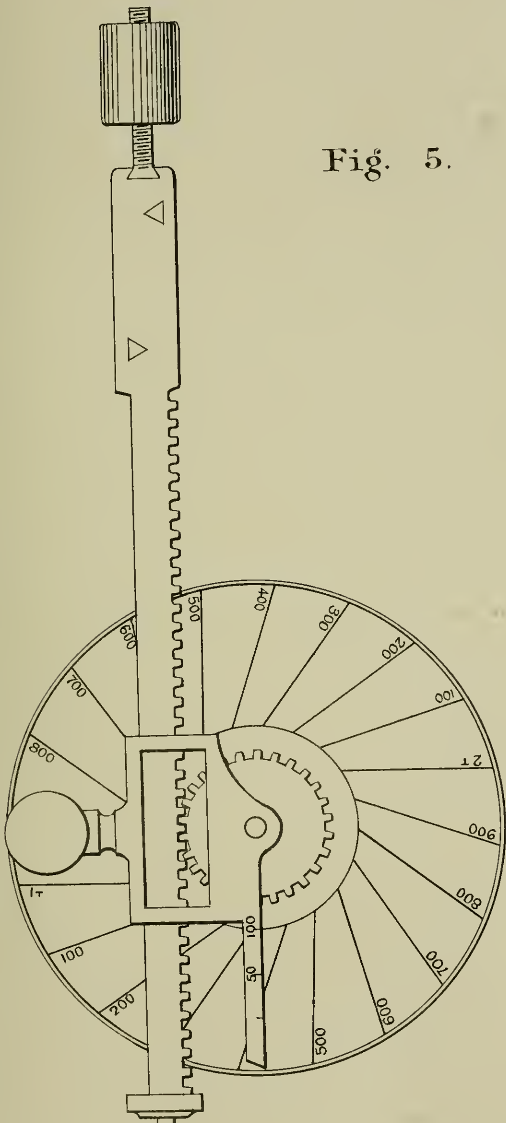

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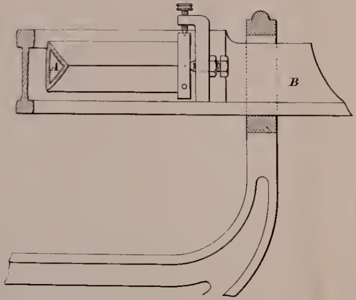
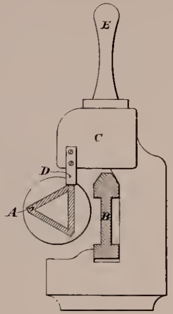
Fig. 5.

Fig. 1.





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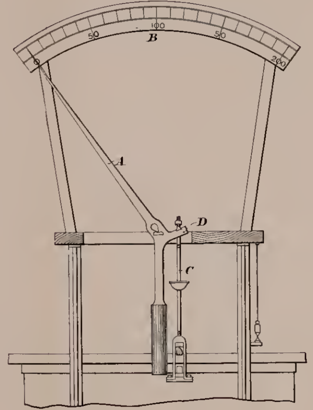
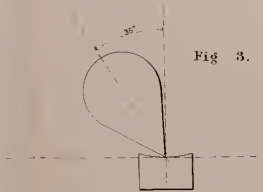


Fig 3.



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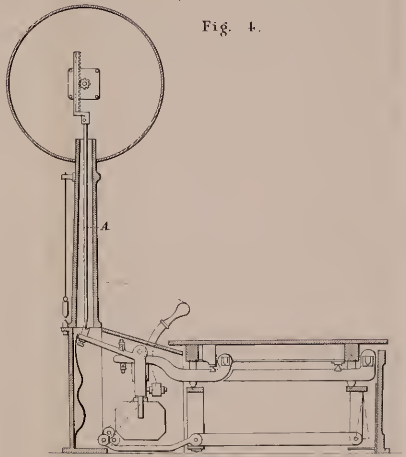

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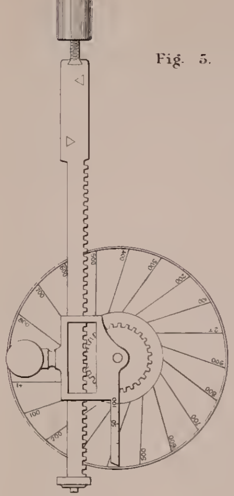

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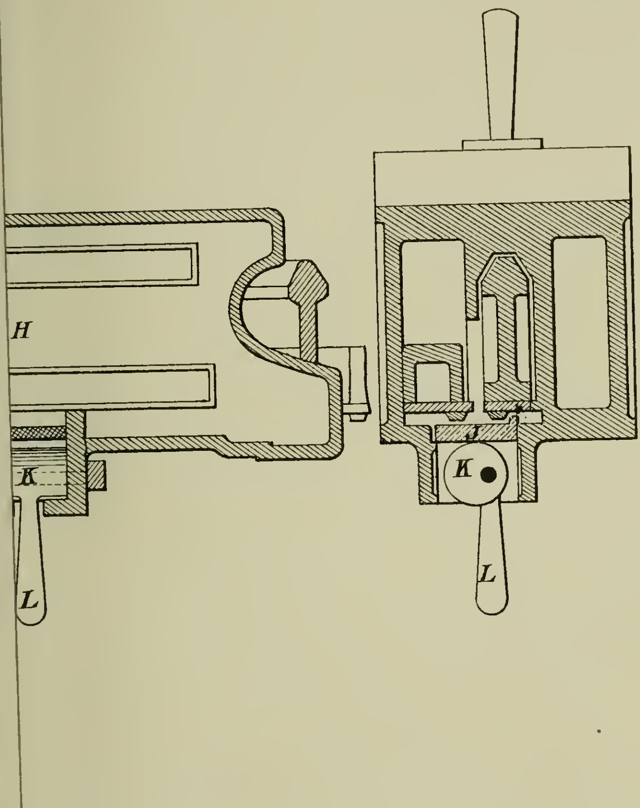
Fig. 9.



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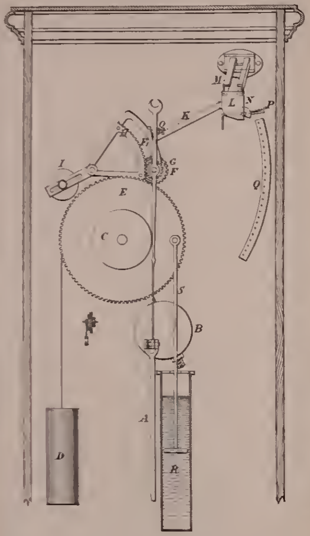


Fig. 7.

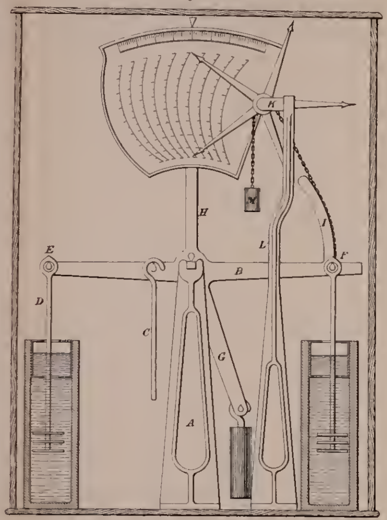


Fig 8.

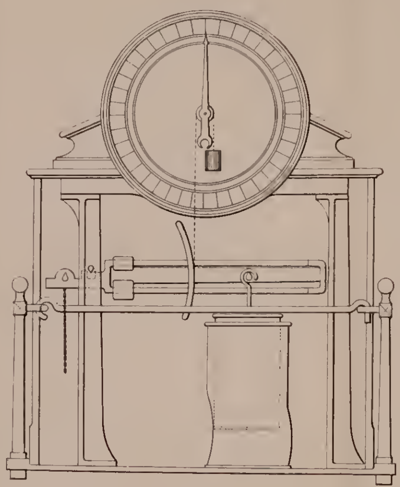
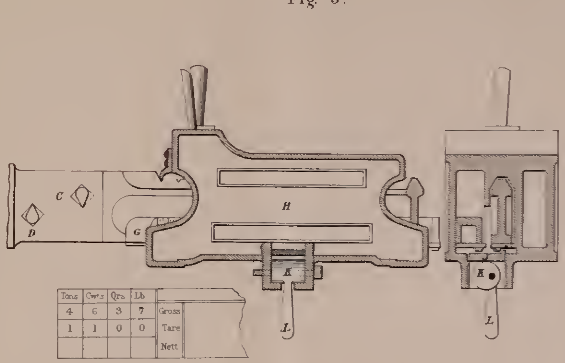


Fig. 9.



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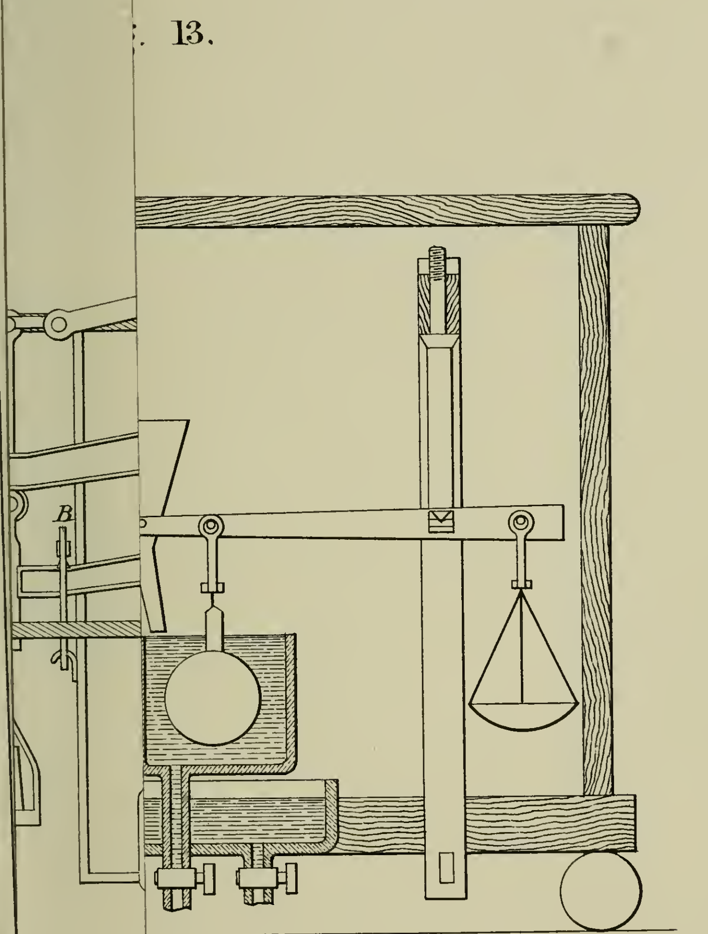

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Fig. 10.

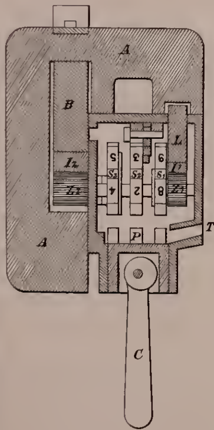
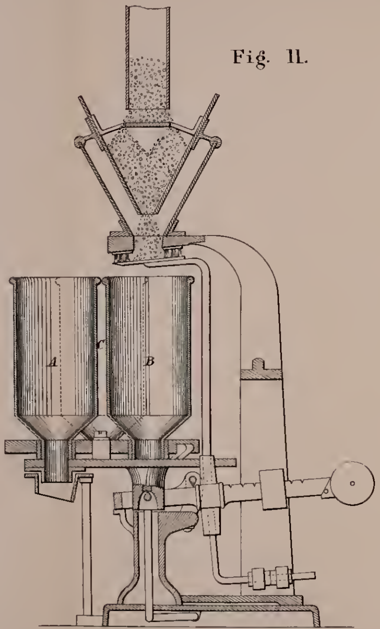


Fig. 11.



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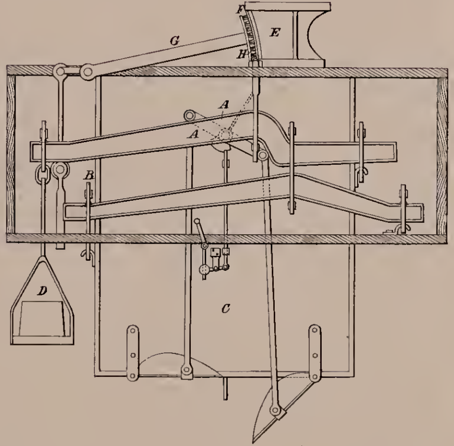

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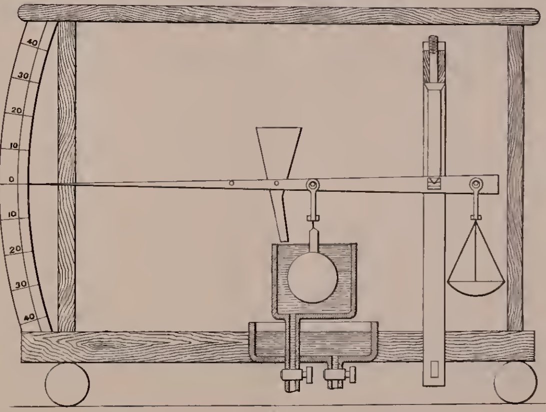

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May 5th, 1890.

HENRY ADAMS, President, in the Chair.

BREAKWATER CONSTRUCTION.

By Frederick Henry Cheesewright, Assoc. M. Inst. C.E.

In bringing the subject of breakwater construction before the Society of Engineers, the author proposes in the first place to give a short chronological history of harbours from the earliest times to the present day, and in the second to enter somewhat into the details of the methods of construction employed in the more recent examples of such structures. He will refer to certain constructive failures and their causes, after which he will describe a new system of this class of construction by John Lewthwaite.

As a fallen tree or a floating log may have given to the inhabitants of Tyre, the earliest sea-going people of whom there is any record, the first idea of a ship, so doubtless, artificial breakwaters originated from the models supplied by nature herself in the projecting promontories of a rocky coast. The Tyrian sailors storm-tossed in the Ægean Sea would find shelter in the smooth water formed by the jutting horns of a land-locked bay, these promontories breaking with passive yet stubborn force the fierce tumultuous masses of water hurled against them by the outer sea, and it is probable that the experience thus gained upon the coast of Greece with its countless natural harbours would suggest to the Tyrians a way of rendering their own port, lying on an exposed and unprotected shore, accessible in all states of weather, by the construction of their famous mole. At first maritime communities probably confined their voyages to ports which possessed safe anchorage; but with advancing time it would often happen that large populations, attracted by local advantages such as a healthy site or a fertile soil, would settle on various points of the sea-board affording no facilities for the reception of shipping. Increase of wealth would form the incentive for opening communication with other nations, and art would then be called upon to supply what nature had withheld. These earlier protective works consisted of large masses of stone piled at a suitable spot upon

the sea-shore, and the heap gradually prolonged seaward, just as at the present day a railway embankment is carried across a wide-stretching valley. This system of barrier or breakwater construction was that first adopted; and, strange to relate, in its essentials it is the only one that the ingenuity of man has up to the present day been able to conceive: for although modern engineers have modified, varied, and improved the system, it is no exaggeration to say that in all the main features the latest magnificent structures erected by our most eminent engineers are not one step in advance of the primitive mole, the work of hands that had returned to dust before the British or the Roman name had been heard of. It is not the author's intention to deny that improvements have been made, but so far as the main idea in the construction of breakwaters is concerned, it must be admitted on all hands that it was tumble-stone at the beginning, and is tumble-stone now. Nowhere has the daring of man been more apparent than in his struggle with that most unstable yet most powerful of all agencies, water. To erect sea works that stand at all against the terrific forces of sea-waves hurled in endless succession against them by a wind travelling at the rate of 100 miles an hour is an undertaking that might well shake the resolution of the boldest. Yet it has been done in all ages, and on almost every coast. History, that notices and hands down to future races the names of those who have been the scourges of mankind, has too frequently allowed to drop into oblivion the names of the dauntless engineers who, by their mighty structures, combated even the ocean, and have offered to the storm-tossed ship a refuge upon an exposed and inhospitable shore.

It may be well at this point to give a somewhat fuller description of the system of construction hitherto employed, both by ancient and modern engineers, before proceeding to consider in detail some of the typical breakwaters of the world. As previously stated, this system comprises the tipping of large masses of tumble-stone or *pierres perdues* into the sea until the rubble mound reaches the surface, where it acts as a shingly beach to receive the impact of the waves. As the continued action of the waves gradually lowers the top of the mound and flattens the sea-slope, the surface of the mound has consequently to be continually fed with fresh material until the sea has worn it away to a natural slope. When this slope has at last been attained, very little alteration takes place from the bottom to a point near low-water mark; but from thence upward the mound is always liable to destruction, or at least great injury, and must always entail great expense to keep it in efficient repair.

The celebrated Cherbourg breakwater (Fig. 11) was first formed in this manner, but, as after every storm the mound was reduced to low-water level and the harbour fully exposed to wind and wave, it became necessary to erect upon it as a basis the present magnificent superstructure. Our own Plymouth breakwater was similarly constructed, and was found to be equally unable to bear the action of the sea. Pitching, with flat stones firmly set in cement, was resorted to, and with fair success, but when once any displacement took place in regard to these surface stones, unless the breach was immediately repaired, the sea rapidly enlarged it, and would in a short time have carried away the whole of the protecting surface, one wave being known to have ripped up as much as 70 feet. Another development of the tumble-stone system was the employment of concrete blocks for the formation of the mound at places where suitable stone was not to be obtained. Types of the concrete-block mound are the Biarritz breakwater, that at Leghorn, and the major portion of that at Port Said. The varieties of the tumble-stone system are too numerous to be fully gone into; but, as approximating most closely of them all to the system proposed to be specially described, it may be well to mention the pile-driving system, by means of which the waste of the mound is to a considerable extent prevented. But whatever has been done by different engineers, many of them men of the greatest eminence, nothing would appear to have been discovered which supersedes the system of making a foundation of rubble or *pierres perdues*, and building upon it structures of stone or concrete. It may be further said that whatever improvements the ingenuity of man has devised, in the way of binding together these structures, either by iron clamps or dove-tailing the stones one into another, they have all been failures in a greater to less degree; moreover their cost has been enormous, and, in the few instances where a fair amount of efficiency has been obtained, it has been gained at the cost of thirty or forty years of incessant labour, armies of men being employed daily in tipping vast quantities of material into the sea for the sea to arrange and rearrange at its pleasure. The Cherbourg breakwater actually took seventy years in constructing, having been commenced in 1783, and not finished until 1853. A very important point, which must not be lost sight of, is revealed by a casual glance at any of the diagrams representing the breakwaters referred to in this paper. It will be noticed that in order to secure a basis for a superstructure of comparatively small dimensions, it is necessary to encroach upon the waterway to the extent of at least ten times the basis required. Where the entrance to the port is suf-

ficiently wide to allow of this encroachment, the only thing to regret is the enormous waste of money and material incurred; but where the entrance is narrow, it is evident that it puts an end to the possibility of building a breakwater at all, for by the time there was a sufficient basis formed for its erection, there would be no waterway left for ships to enter the port. It is owing to this important drawback that marine works have not been carried out in many of our provincial ports, especially in the colonies, which greatly require them.

It would be undesirable in this paper for the author to go into the question of the varying forces of wave-power, or into the theories of wave-action, and it is only necessary to deal with their results, which are certain and defined. One thing, however, it is very necessary to bear in mind, and that is the well-known fact that a breaking wave exerts more percussive and destructive force than an unbroken one, also the admitted fact that waves begin to break when they enter a depth of water roughly approximating to their own height. It therefore follows that the very foundations of our present breakwaters, built on the talus or *pierres perdues* system, are themselves unceasingly assisting in the destruction of their own superstructures. This was very forcibly brought out at one of the sittings of the Select Committee of the House of Commons on the Dover Pier and Harbour Bill in 1875. The chairman (Sir Seymour Fitzgerald) put the following question (1676) to Captain E. K. Calver, R.N.:—"The stability of an upright wall must depend upon the thickness of the wall?" and the witness answered, "It must depend upon the inertia of the mass and upon the profile. If you put a long batter on to a marine work and create a wave, you bring into operation a power for its own ultimate destruction. On the details of construction I would not say a word; but upon matters of general design my experience is directly applicable." Further proof as to the inefficiency of the present system of construction may be obtained from the minutes of evidence taken before a Select Committee of the House of Commons, on June the 15th, 1883. In question 1513, Sir John Coode was asked if he was aware that the great drawback to the formation of, and great hindrance to harbours, hitherto has been the great failures that have taken place in the harbour construction? Sir John replied, "I know that that has been a drawback, it has probably made the authorities timid in incurring a large expenditure." Question 1514, was then put to him as follows:—"Are you aware that ten millions sterling have been expended by the Government mainly in what are called Harbours of Refuge, and that excepting that magnificent work of yours, the Portland Breakwater,

you may say that probably nearly the whole of the other harbours have been failures; for instance, Alderney?" Sir John replied, "Alderney has not been satisfactory, certainly."

An additional proof that the field is open for a new system of construction, it may be well to quote the following paragraph from the Appendix to the Report of the Select Committee on Harbour Accommodation, July, 1884:—"The next important point deserving of attention is the remarkable diversity of designs put forward by different engineers for Sea Harbour Works, and the often defective results as regards outlay and failure in the works. This may be reviewed as the result of long years of delay in carrying out harbour works, where the engineers who commenced seldom have lived to witness the completion of the works, and, consequently the defects in any particular harbour have rarely been remedied in another one designed by the same engineer. We have no hesitation in stating that there is hardly a single harbour at home which will not show some defect worthy of being avoided in all future works; and a wasted outlay which must be burthensome to the nation." It would be difficult to sum up more tersely the absolute inefficiency of the present system of breakwater construction, than is done in the above paragraph by a body of experts appointed by the highest authority in the land as being the best men the country could find for the purpose. The chairman of that same Committee read the following paragraph of a letter from Provost Rae, referring to the disastrous failure at Wick, "The unfortunate breakwater was an engineering experiment; and although a ruinous burden to Wick, it has been worth the money to the country, in showing how not to do it again." Perhaps it is only fair to add that Provost Rae was writing with a view to getting the country to share the burden of the failure with Wick.

The author will now proceed to give a short sketch of some of the typical breakwaters of the world, beginning with the more ancient, and giving in connection with each such details as may be of interest to the meeting or may serve to illustrate the mutifarious difficulties with which engineers have had to contend, and also a system by which it is hoped they may be successfully overcome.

One of the most ancient, if not actually the most ancient, breakwater in the world is the famous mole of Famagousta (Fig. 1) in Cyprus. It is formed of loose rubble, the stones weighing roughly between two and three cwt. each. The top is capped with a layer of squared stones averaging 3 feet long and 18 inches wide, which are bedded and jointed in mortar. This top is now destroyed, and its debris has considerably

narrowed the entrance. The difference in the ground level on the sea side and harbour side is worthy of notice.

Another ancient breakwater deserving mention is that at Civita Vecchia, constructed by order of the Emperor Trajan about A.D. 100. From the account given by Pliny the younger, it would appear that it was made in a very similar manner to that adopted in our own day at Plymouth (Fig. 5), which does not say much for progress in this direction during seventeen centuries!

Coming to modern breakwaters, we have that at Alexandria (Fig. 2), which has a depth of 5 fathoms and upwards, and shelters 1400 acres. It was begun in 1870 and completed in two years. This remarkably short time in constructing a very large work was due to the enormous quantity of forced labour employed, and to the fact that there was no tide to contend against. The breakwater mole, quays, and other harbour works cost about 2,000,000*l.* The detached breakwater, which is 9675 feet long, is composed of concrete blocks which are $11\frac{1}{2}$ feet by $6\frac{1}{2}$ feet by 5 feet, and weigh 20 tons, they were kept for three months to harden before being employed upon the outside of the work, the inside of which is composed of rubble and large stones.

The Marseilles breakwater (Fig. 3), was begun in 1845, and took 36 years in construction, being finished in 1881. Its total length is 11,930 feet, its width 59 feet, and depth $6\frac{1}{2}$ to 12 fathoms. One portion cost 75*l.* 11*s.* per lineal foot; the portion opposite the Lazaret and Arene basins, 2050 feet long in a depth of $55\frac{3}{4}$ feet, cost 109*l.* 14*s.* per foot, and the portion in front of the Maritime basin, in a depth of 52 feet, and having a length of 1660 feet, a similar sum. This structure is composed of a rubble foundation supporting coursed masonry faced seawards with blocks of cement weighing from 20 to 30 tons.

The harbour at Algiers (Fig. 4) is protected by a rubble and concrete block breakwater of similar construction to those at Port Said, Biarritz, and Alexandria. It is, perhaps, unnecessary to remind this meeting that what stands very well in the tideless and fairly peaceful Mediterranean would probably prove worthless if exposed to the terrific forces of an Atlantic storm.

From an inspection of plans of harbours it will very readily be seen that the breakwater at Cherbourg (Fig. 11) is one of the largest marine works ever undertaken, and that it has not been exceeded, as regards extent of area sheltered, by any more modern works. The Alexandria breakwater indeed approaches it in length, whilst the mattress jetties at Galveston and Charlestown even exceed it, but considering the solid nature of

the work, the powerful batteries which it supports, and the period of its construction, it must be admitted to be a marvellous piece of engineering skill and perseverance. It does not equal in depth and in section several other breakwaters, but it furnishes a perfect type of a breakwater formed of a rubble mound, supporting a superstructure of concrete blocks and masonry, starting from the low-water level. This famous work was begun in 1778, stones being tipped in until high water mark was reached. Waves and storms continually beat the top of the mound down to low-water level, the debris considerably enlarging the area of the tumble-stone foundation, while the sea action materially altered the shape it was intended to have taken by its engineers. In 1832 an upright wall was built on the top of the mound, and the whole works were completed in 1853 at a cost of 2,674,491*l*. The superstructure successfully supplies the place of the weak part in the rubble mound, and fulfils precisely the object for which it was designed, while the rubble is not carried higher than is just required for the protection of the foundation course of the upper works. Since the success of the system employed at Cherbourg has become known, many other noteworthy and fairly successful structures have been similarly raised, but in some cases without allowing sufficient time for the settlement and changing of the mound before proceeding to raise the superstructure upon it. It is, perhaps, not surprising that but few engineers have the patience to wait thirty or forty years for their foundations to properly settle. With regard to the cost of Cherbourg, it is only fair to state that the sum just named includes the cost for the foundation of the central battery and some other works not strictly incidental to the construction of the breakwater proper. M. Bonnin puts the actual cost of the breakwater at 2,000,000*l*. which gives an average of 164*l*. per lineal foot.

A very fine specimen of the tumble-stone and superstructure formation is the famous breakwater at Colombo (Fig. 10), of which the foundations were laid in 1875. On the *pierres perdues* base, it has a concrete block superstructure, begun in 1874, the blocks being from 16 to 33 tons in weight, and were deposited diagonally by a steam Titan. During the monsoon season, from May till October, the work had to be altogether suspended. In 1878, during a very severe south-west monsoon, a length of 150 feet of the superstructure was considerably deflected. The maximum advance made with the works during any one month was in January, 1880, and amounted to 154 feet. The depth of water at the outer end of the structure is 6 fathoms. It is of interest to know that the breadth at the bottom of the wall is 26 feet, while at the top it is 24 feet;

that is to say, the Colombo breakwater is a specimen of a nearly vertical breakwater, the great desideratum in such structures. When the harbour is completed the area sheltered will amount to 255 acres, having a depth of 20 feet at low water, whilst the total acreage of sheltered water at low water will amount to 502. The concrete blocks, of which the breakwater is composed, are formed of six parts of broken stone, two parts of sea-sand, and one part of Portland cement. The total length of the Colombo breakwater is 4150 feet, and its depth is 40 feet. The works averaged a cost of 170*l.* per lineal foot.

Attention may here be called to the fact that, with the introduction of Portland cement for the formation of concrete, a very valuable auxiliary has been available for building sea-walls, breakwaters, &c., and there are already many other structures, besides Colombo, of considerable note in which this material has played a very successful part, in fact so successful has it been that it has now become an indispensable factor in the construction of all sea masonry.

The first type of an English breakwater that will be considered is the well-known one at Plymouth (Fig. 5). The famous admiral, Nelson's old chief, Lord St. Vincent, first proposed the formation of a breakwater here to Lord Howick in 1806, when the latter was first Lord of the Admiralty, but it was not until 1812 that Messrs. Rennie and Whidby's plan was adopted and the work begun. The mode of construction was by depositing in mid-channel large blocks of limestone obtained from a neighbouring quarry. These blocks were conveyed to the site for the breakwater in vessels of peculiar construction, having openings in their stern, out of which the stones were dropped to the bottom of the sea. In all fifty-three of these vessels, each being of 50 tons, were employed in conveying stone for the construction of the breakwater. From one of these vessels a load of 50 tons of material could be discharged in about three hours. In the course of 1812 the whole of this fleet discharged 16,045 tons of stone; in 1813 the amount discharged in the twelvemonths had risen to 71,198 tons; in 1814 to 239,480 tons; in 1815 to 264,207 tons; while in 1816 it dropped to 206,033 tons. By the time this portion of the work was finished the sum total of the amount of limestone deposited reached the high figure of 1,000,000 tons. The proportionate dimensions of the deposited blocks were nearly as follows:—

Of 5 tons and upwards	12,760 tons.
Of 3 tons to 5 tons	150,593 „
Of 1 ton to 3 tons	309,706 „
Of 1 ton and under	423,904 „

For quarrying this stone the sum of 2*s.* 5*d.* a ton was paid, while the charge for its carriage was about 1*s.* 10*d.* a ton. According to the most accurate calculations the cost of each ton of stone sunk for the construction of this breakwater was about 8*s.* 1½*d.* The total estimate for the completion of this breakwater was originally 1,524,000*l.*, but the sums hitherto spent upon the work amount upon the whole to 1,562,639*l.* Mr. Rennie, the eminent engineer of the breakwater, died long before its completion. Plymouth breakwater, which is thrown right across the middle of the sound, lies nearly due east and west; it stands completely isolated, having a channel half a mile in width on either side of it. It has also two wings, each being 350 yards long. The central part, which is straight, is 1000 yards in length, the wings incline towards the north at an angle of 120 degrees from the straight portion. The breakwater stands 3 feet above the level of the highest spring tide, is 120 yards broad at the base, 16 yards at the top, and has an average height of 14 yards. It has already been remarked that the mole at Civita Vecchia, built seventeen centuries ago, is constructed on almost a similar plan. As will appear when describing Alderney, the cost for the maintenance of Plymouth breakwater amounts to the enormous sum of 5000*l.* a year.

The works at Portland consist of an inner and outer breakwater. Early in the century a breakwater was suggested at this spot by a Mr. A. Lamb, and Mr. Idle, a local Member of Parliament, entered warmly into the matter and was the first subscriber to the necessary funds. The area sheltered is 2130 acres. Although advocated at so early a date, active work was not begun until 1847. The inner breakwater has a length of 1700 feet, while the outer or detached breakwater extends to 6400 feet. The works advanced at an average rate of 450 feet a year. The total sum of money expended on it from the beginning until 1871 was 1,034,000*l.*, a sum equivalent to 127*l.* per lineal foot; but this amount does not appear to include the cost of convict labour. Though the breakwater has had ample time to consolidate, and though the exposure is comparatively moderate, the slopes are still liable to injury from the action of the sea between high and low water levels. In both easterly and southerly gales the stones of the outer slope are displaced by the recoil of the waves, while under north-easterly gales the waves break right over the mound and dash violently against the inner slope. As much as from 500 to 3000 tons of stone have been known to be disturbed during the continuance of a single gale.

The harbour at Alderney (Fig. 7) is protected by a rubble mound supporting a superstructure founded below low water

mark. The depth of water varies from 21 feet to 134 feet at the outer end. The works were begun in 1847, were modified in 1849, again in 1856 and yet again in 1858. The western breakwater was carried out to a length of 4380 feet. Its actual cost up to the period of completion in 1864 was at the rate of 235*l.* per lineal foot. It is worthy of note that from 1875 to 1883 the cost for repairs of breaches alone has amounted to the very large sum of 52,850*l.* This breakwater appears to have been strongly constructed in its upper and monolithic works, but to have been neglected in the matter of its rubble base. The large masonry blocks forming the outer wall are tied or "dowelled" together with huge bolts of gun metal, while the rubble and dry masonry base is being continually worn away by attrition. The same defect is to be seen at Wick, and also at Arklow. Sir Andrew Clarke, R.E., in giving evidence before a select committee of the House of Commons on the Harbour and Fortifications of Alderney (Session 1872), reported that "the cost of Alderney had been 300,000*l.* less than the cost of Plymouth breakwater, which was being maintained at a cost of 5000*l.* or 6000*l.* a year, and he did not think that Alderney was likely to cost more." Not a very hopeful way of speaking of a breakwater which when built at a vast expense is supposed to be at least efficient. Breakwater construction must be in a very bad way when it appears to be a recognised thing that a finished structure should, as a matter of course, require 5000*l.* annually to keep it in repair.

The Admiralty pier at Dover (Fig. 8) is stone built on a rubble * basis in a maximum depth of water at spring tide low water of 45 feet. This pier has a base of 92 feet, and a clear roadway of 30 feet in width. Its sectional area is 4736 square feet, and it cost 360*l.* per foot run. From a Government return of 17th August, 1883, it would appear that the total cost reached 693,077*l.*; but in addition to that a sum of 22,827*l.* has been paid for repairing the damage done by a storm in 1877 and by others in subsequent years. The whole cost has been paid by Parliamentary grant. The original engineers of this magnificent structure were Messrs. Walker and Co., who were followed by Messrs. McClean and Stileman, and at a still later period by Mr. Edward Druce, who had previously acted as resident engineer. Notwithstanding the immense cost and care bestowed upon this really excellent work it is said to now show signs of failure at the base. The cause is not far to seek. It is the same here as in those other cases that have been mentioned where the base consists of either masonry or concrete blocks laid on a loose or rubble bottom, and built or put together under water by divers without any cement or "dowel-

* Chalk. See author's reply, p. 113.

ling" or other medium binding. Dover is but another example of the fact that the present system of breakwater construction, though a very expensive is an exceedingly ineffective one. Mentioning Dover brings prominently to mind the fact that the authorities themselves appear at length to have arrived at the same conclusion, and that they seem to be holding their hand awaiting some new development of engineering skill. For a long while Government has entertained the idea of building another breakwater at Dover in order to make it a harbour of refuge. Plans and estimates have been submitted during the past fifty years by such very eminent engineers as Mr. James Abernethy, Mr. Michael Scott, Mr. James M. Rendel, Mr. William Cubitt, Captain Vetch, R.E., Mr. Charles Vignolles, Lieut-Col. Harry D. Jones, Sir John Rennie and others. Yet not one of these plans has been considered suitable, and the matter still remains in abeyance, partly from the want of suitable material in the neighbourhood, partly from the great cost attending the preparation of foundations fit to support a superstructure capable of standing the action of the waves. The estimates which have been sent in vary from Colonel Jones's 1,100,000*l.* to Mr. Cubitt's 5,000,000*l.*

The breakwaters at Tynemouth (Fig. 9) are other instances of the destructive action of the sea, even at a depth of 12 feet below low-water level, on small rubble supporting a high superstructure. These breakwaters, which are perhaps unequalled as examples of engineering skill, are formed of concrete blocks of peculiar shape built on shore and thoroughly well aired before being lowered by a very powerful "Titan" on to each breakwater, where they are set in position by divers. The operation is very slow and costly. The work was begun more than 30 years ago, and is not yet finished. Up to 1879 the North Pier cost about 160*l.* per lineal foot, and the South Pier about 75*l.* The North Pier has a length of 2900 feet. The breadth at the bottom is 52 feet and 35 at the top. Their height varies from 58 to 61 feet. From time to time great damage has been wrought to their respective bases during heavy gales.

For the Holyhead breakwater (Fig. 12) an abundance of stone of excellent quality for the work was obtainable at the quarries on Holyhead mountain, only about a mile off. The design adopted for the breakwater was that of a rubble base with a superstructure on the harbour side of the mound springing from low-water level, the building being a sea harbour wall of masonry composed of large blocks of stone set in lime mortar. This sea wall not only provides an upper roadway or promenade at the top, which is $21\frac{3}{4}$ feet above high water, but also shelters the quay level, which is $11\frac{1}{2}$ feet below the upper level. The quay has been formed by the deposit of suitable small material

on the mound above high-water level between the sea and harbour walls. The breakwater has an average depth of 40 feet, and extends into a maximum depth of 55 feet with a slope on the sea side of about 12 to 1 between high and low water, 5 to 1 from low water to a depth of about 12 feet, and about 2 to 1 from thence to the bottom. On the harbour side the slope is about $1\frac{1}{4}$ to 1 throughout. The total amount of stone in this stupendous mound is 7,000,000 tons. Holyhead breakwater was begun in 1849 and finished in 1873 at a cost of 1,285,050*l.* As the length is 7860 feet, this gives 163*l.* 10*s.* as the cost per lineal foot. The cost of a bay of 30 feet of the staging alone amounted to 586*l.* 10*s.* The charges for the maintenance of the mound have hitherto for the most part been very slight. At the extremity, however, the mound tends to travel round the head, and is not quite stable; it has therefore been found necessary to protect the rubble slope for the last 200 feet on the sea side near low-water mark. This was first attempted by throwing down concrete blocks; but, as there was no adequate machinery for depositing the blocks, they got broken by the fall. Eventually old chains, amounting in weight to 1000 tons, were placed in long coils upon the foreshore, and by their weight these keep the foreshore from shifting, while, at the same time, they do not offer a solid face to the blow of the waves. A breach occurred in the breakwater last November by which some hundreds of tons of work have been displaced, and it is now very liable at any time to suffer considerable damage.

The breakwater at Wick (Fig. 13) is yet another example of the rubble base with block and concrete superstructure. It was begun in 1863, and in 1867 the pier had been advanced about 820 feet, while the rubble base was carried some 230 feet further. The first material damage sustained occurred in December 1868, when the outer portion of the superstructure was seriously damaged, the whole of the foundation from the level of low-water mark to 10 feet under it being uninjured, but the rubble base had, in some parts, been washed down to about 15 feet under low water; in 1869 the damage had been repaired and reconstructed in cement, but in 1870 a severe storm occurred, and a length of 380 feet was damaged seriously. In 1871 about 30 feet of the outer end was damaged, and large blocks were built on the beach, of cement rubble concrete, of from 70 to 100 tons each, and floated out by barges at high water and deposited on the rubble base in advance of the proposed forward work. In 1872 further damage was sustained, and Mr. Rendel (now Sir A. M. Rendel), being called upon to examine and report, attributed the failures of the work in 1868–70 to its want of "sufficient unity." In December of that year it was again

attacked by a storm of great fierceness. Once more the storm, in December 1872, though not so disastrous from a pecuniary point of view as the storms previously experienced, was far more serious as regards the character of the damage done. The end of the work was protected by large blocks of 80 to 100 tons deposited as a foundation by three courses of large stones carefully set in cement, and the whole surmounted by a large monolith of cement rubble weighing upwards of 800 tons. This block was built in situ, and as a further precaution iron rods of $3\frac{1}{2}$ inches diameter had been fixed in the uppermost of the foundation courses of cement rubble, carried through the three courses of stone work by holes cut in the stone and finally embedded in the monolithic mass forming the upper portion of the pier. Yet the whole of this enormous work, weighing not less than 1350 tons, succumbed to the force of the sea. During the course of the storm it was actually seen, from an adjacent cliff, to gradually slew round beneath the force of successive wave strokes until it finally tumbled over into the bay, where it has since rested.

The final example that will be taken of an existing breakwater is that of Aberdeen. This was begun in 1870 and finished in 1873. Its length is 1050 feet, and it is 35 feet wide at the head of the roadway, having a uniform batter of 1 foot horizontal to 8 feet in height. The landward end for 500 feet in length towards the sea is founded on rock, and the remainder on a bed of boulder clay which had been covered with a thin layer of stones and sand. Of course the sand was cleared away in order to secure a solid foundation before the works were proceeded with. The manner in which the natural inequalities of the foundation were overcome was by levelling up with a deposit of concrete in small bags on which blocks of Portland cement were built without being cemented.

These blocks, weighing from 10 to 20 tons, were carried up to a uniform level of 4 feet 9 inches above low water of spring tides, except at the seaward end, where they were terminated at 9 inches above low water of spring tides. The blocks are composed of one measure of Portland cement, four measures of pit sand, and five measures of stones. The concrete superstructure, 18 feet in height, was built over the blocks in frames, in situ, a large number of blocks being incorporated with it. The superstructure is composed of one measure of Portland cement, three measures of pit sand, and five measures of stone or shingle. An apron of concrete deposited in bags lies at the bottom along a part of the sea, or east side of the foundation. It commences about 600 feet from the shore, or about 100 feet from the rock foundation, is then carried round the head of the

breakwater, and returned along the harbour side for 110 feet. There are two rows of piles along the breakwater, placed at 18 feet apart. Each pile is 2 feet in diameter, and passes through the whole depth of the work. The piles are stepped into iron shoes at the foundations, and where they pass through the substructure are surrounded by blocks moulded to the form of the piles, the junction of the blocks being formed at the middle of the pile. The upper foundation courses of blocks, have sustained damage along the whole length of the breakwater on the sea face, and along a part of the harbour face. The holes excavated in the upper courses have hitherto been repaired at low water of spring tides by filling them up with small bags of concrete, and finishing the surface with a facing of Portland cement mortar. These patches have stood well with the exception of the repairs at a point 500 feet from the commencement of the breakwater. The breach at this point was further repaired during the summer of last year. These repairs, however, again gave way last winter, and the breach was enlarged by successive storms from the north-east to the dimensions noted in the reports of the 6th February, 10th March, and 18th May. The survey made on the 6th February showed the hole to be 22 feet in length by 12 feet deep, extending along one row of blocks, or 8 feet into the breakwater; the survey of the 10th March showed an increase to 72 feet in length by a depth varying from 4 to 12 feet, with part of the inner row of blocks removed; and on the 18th May this breach formed a cavern 90 feet in length by 12 feet deep, and 23 feet into the breakwater. On examination of the breach by divers, the foundation of small bags of concrete, on which the blocks rested, was found to be removed from under the blocks to the seaward of the hole for a length of 18 feet. The superstructure was split vertically 150 feet along the middle of the breakwater over the hole, forming a separate mass of 2500 tons weight, which rested as a flat arch entirely on the blocks at each end of the breach.

Mr. Smith, the resident engineer, explains this disaster as follows:—"I am of opinion that the concentrated waves from the north-east coming upon the junction of the rock foundation with the stratum of stones on boulder clay at this point, in a depth of 13 feet at low water, swept out the concrete in small bags, relieving the concrete blocks from the weight of the superstructure. At low water the top of the breach was exposed to the air, the sudden compression of which, by the water flowing after the wave again covered the entrance, blew out by its explosive force the blocks on both the harbour and sea face of the breakwater."

The superstructure was also damaged on the sea face close to the lighthouse tower, a breach being formed 54 feet long by 22 feet deep, and about 4 feet into the breakwater. At a point on the sea face, 100 feet landward from the tower, another breach was made, extending partly into the base of the superstructure and the upper course of blocks. The blocks composing the substructure were found to be chipped and abraded on the sea face, especially near the level of low water, and the piles, where they pass through the superstructure, had been eaten away by the sea-worm (limnoria-terebrans), leaving spaces 2 feet diameter between the blocks. The cost of repairs was estimated at 27,000*l.*

A great advance was made in the construction of breakwaters in the case of Wicklow Harbour Works (Fig. 18). Mr. William George Strype, M. Inst. C.E., there adopted for the first time the bold method of erecting a sea-wall, in a very exposed position, by means of concrete entirely laid *in situ.* The following is Mr. Strype's own description of the method of construction, as given in that gentleman's evidence before a Committee of the House of Commons:—"We claim that the system we have adopted in the construction of the Wicklow Works is a novel system. I have prepared a diagram that will show the Committee the system of construction that has been adopted there. In other ports, such as Newhaven, and I believe also in the exposed work at Fraserburgh, the part below water was laid by means of concrete in bags; the concrete is put in long bags contained in hopper barges. The hopper barge door is slipped, and the concrete bags drop to the bottom. These are piled upon each other, and raise the structure to low-water mark. At Wicklow we adopted no such expedient as that, but in constructing the work we first formed a great central staging, on which the engines, the waggons, and the cranes ran. That was extended in advance of the work to about half the length of the breakwater, and the staging trestles secured by means of a pad of concrete (cross section No. 1, Fig. 18). We deposit a pad of about 70 to 80 tons of concrete; No 1 shows that pad. We carried the trestles thus secured by pads of concrete (as will be seen by the elevation), a long distance in advance of the general progress of the work. As soon as the staging was secured by this means, we deposited a great mound of concrete (cross section No. 2, Fig. 18), which shows the mound of concrete, representing about two-thirds of the volume of solid structure below low water. That great mound steadied the staging considerably, and also admitted of very rapid progress in the construction of the works. We were able during the construction of the mound to lay about

2000 tons a week, and for a little work that is considered, a very remarkable pace at which to lay concrete. Upon the mound we added an outside deposit of concrete to the form of the breakwater, by means of a panel rendered heavy so as to make it sink. We raised this deposit to within three feet of low-water line. The difficulty with this system of construction is more when you get near to the level of low water. At low water the disturbing waves are apt to wash the cement out of the concrete before it is set. By putting our first stretch of panel within three feet of low water, we are able to deposit or form the first profile toe to within three feet of low water. As soon as that sets, which it does in a day or two, we put a panel from that above the level of high water, and then lay a further portion of the profile. For that further portion we select very calm water, so as to avoid disturbance of the work; that is the most trying part of the work while the structure is being formed; as shown in cross section No. 3, Fig. 18, we carry up the inside to the height of low water. The work being over low-water mark is quite easy, and cross section No. 4, Fig. 18, shows simply the building of superstructure, which can be readily accomplished. The volume of the breakwater is about 40 cubic yards per foot run, and the cost of the work, which we paid, is 17*s.* 3*d.* per cube yard; so that it comes to under 40*l.* per lineal foot. I am satisfied we could carry out this work in water 50 feet deep, by making modifications in the system. We found the least loss of timber and the least loss of concrete in every part of the work until we got within three feet of low water. Up to three feet of low water no trouble existed; we never lost a single cubic yard of concrete in that lower work, and the work was frequently visited by storms, and we frequently deposited concrete with a wave of three feet undulating."

The author thinks that without referring to any further examples, although many more could easily be cited, a sufficient case has been established to show that the present system of breakwater construction is thoroughly inefficient. Even with the most generous exchequer to carry out designs and plans, he maintains that hereafter both money and time will be again spent in vain, and that fresh failures will result, unless a totally different system of construction be adopted.

All practical and theoretical experts are agreed that what is wanted is a vertical wall, or a wall as vertical as it is possible to obtain. For many years a great difference of opinion existed among engineers and scientific men, as to the relative advantages and disadvantages of the long slope and vertical wall systems of construction; many authorities insisting upon

the theory that in the case of a vertical wall, rising from the bottom in deep water, the wave is a simple undulation, and that it would rise up against a vertical face and act by its statical pressure only; whereas in the case of the adoption of the long slope the character of the wave would be so completely and entirely changed, that it would have a considerable amount of progressive motion imparted to it, and consequently great percussive force, the result being, that the whole weight of the mass of water, multiplied by the velocity with which it was moving, would be the measure of the force exerted on the slope; or rather upon the vertical wall reared at or near the termination of the slope.

Sir George Airy says that "waves do not break against an upright surface, and exert no percussive force upon the wall, they will exert the same sort of pressure that there is against a lock-gate, that is a hydrostatic pressure."

Sir William Cubitt also says that "if in constructing a wall in the sea, 72 feet high, in deep water, we could be sure of all our premises, the thing could be done and would be the most perfect."

Capt. Veitch says that "he would prefer a wall of solid masonry rising boldly and perpendicularly out of deep water, but for the expense and difficulty of preparing foundations and carrying on such structures, as the time and expense would be so great 'on the usual mode of procedure' as to render it impracticable."

It may therefore be taken that there is a general concensus of opinions, first, that an upright wall is best adapted to repel heavy waves; second, that it should rise direct from the bottom of the sea; and, lastly, that the great drawback to the construction of works of this description has been the cost and difficulty of preparing foundations for them in deep water.

A very fair contrast may be drawn between the breakwater at Plymouth and Dover. Plymouth breakwater is a sloping one while that at Dover is an upright wall. They are somewhat similarly situated with respect to exposure to south-westerly gales, the height of the waves at Plymouth being 13 feet and at Dover 12 feet; during these gales the sloping breakwater suffers considerable damage in its "toe" and "head" while the upright wall receives no damage whatever. Moreover, taking into consideration the supposed more exposed position of Plymouth breakwater all the more important advantages of such structures as shelter for shipping remains with the upright wall; and in regard to the expense of maintenance, we have seen that the Plymouth slope may be put down at 5000*l.* per annum, while the upright wall is nil.

The vast expense necessary for the erection of breakwaters on

the old system, has proved too frequently an insurmountable obstacle in places where they were much required. Frequently half measures have been resorted to, and with the result common to half measures at all times and places, a dead loss of the money expended and no benefit obtained. It is no exaggeration to say that the colossal sums of money which have been fruitlessly cast into the sea in the construction of futile breakwaters amount in the aggregate to a national loss or disaster. The history of those ports which have been erected by private and local enterprise presents but a record of building make-shift piers at a time when funds were low and of taking them down again when trade had expanded and more room was required. The want of funds has prevented too frequently the original work from being carried into deep water, and in consequence the most expensive part of the projecting breakwater is often put down at the very place which has afterwards to be converted, at great expense, into deep waterway or berthage.

The author has now to call the attention of the meeting to the invention of Mr. John Lewthwaite for erecting upright walls in any position however exposed, and on any foundation, whether it be rock, sand, reef, or mud. Fig. 14 shows Lewthwaite's patent in elevation as adapted on an uneven rocky bottom where rock in any quantity can be obtained for filling; whereas, Fig. 15 shows the system employed on a sandy or soft bottom where only silt, sand, chalk, or other material of a loose nature is obtainable. In this latter case it will be seen that the loose filling is kept in place by concrete blocks which are made to any desired dimension, the size being regulated by the amount of sea to be resisted. Fig. 16 shows a cross section with details of all parts that are necessary to construct a breakwater or sea-wall of any size in any depth of water, let the nature or contour of the bottom be what it may. One of the most important merits claimed for this invention is its simplicity of construction, there not being one piece in any of the varieties of construction requiring the hand of the skilled artisan. But though an important merit, this is by no means the only one. Works on this system can be carried on with very great rapidity in almost any weather short of a hurricane; staging, that most expensive of items, is only needed when the breakwater is not connected with the shore. Another distinctive characteristic of this new system is, that the construction is one connected whole, and, therefore, unlike any breakwater or sea-wall yet erected, perfect continuity is obtained. Again, there need be no fear about the works receiving damage during the course of construction, as

by this system, and this system only, the upright or vertical wall from the sea-bottom to any desired height above water is rapidly and easily attained.

The method of erecting works on this principle is to form two horizontal booms parallel to each other, spaced the distance apart required for the two outer walls. In order to form an absolutely stable structure the width should be about equal to the depth of water, i.e. if there be 40 feet water, the breakwater should be 40 feet wide. These horizontal stages have slotted pieces of iron, termed grippers, entending their entire length, placed at intervals, and so disposed as to hold the upper ends of the vertical rods in position when dropped by the overhead traveller used in the construction of the work. These operations are carried out simultaneously on either side. When a rod on each side has been dropped, a transverse tie is threaded on, the grippers are drawn back, the tie allowed to pass, the grippers replaced on the rods, and the tie then lowered. This defines the transverse distance of the vertical rods. Other rods are then lowered in the same manner, and links are threaded on to them in the direction of the work to be done, each link being threaded over three rods. When a rod has three links on it the grippers are drawn back, and the links allowed to drop. The grippers are then replaced, and the rods again secured to them in their proper position. Should the construction be similar to that shown in Fig. 14, pieces of tube, termed "distance pieces," are threaded over the rods to regulate the distance between the links vertically. As will be seen by reference to this figure, the distance pieces are of varying lengths, when the bottom is uneven, until a horizontal line has been attained. When this has been accomplished the distance pieces used will be of equal lengths, and the work continued in a regular and consecutive manner, until a further dip in the foundation is encountered, when the distance pieces will again be of various lengths until another horizontal section has been attained, and so on to the end of the work. The above sketch shows these distance pieces in the regular part of the work to be 6 feet long, so that the cable links will be kept at that distance apart throughout the structure. The distances that these transverse ties are to be placed may be left to the discretion of the engineer. When this part of the work has been accomplished rock filling is thrown in, shoots being of course employed in order to prevent any damage to the transverse ties. The same process is carried out when forming a breakwater as shown on Fig. 15, only that no distance pieces are required, the concrete blocks themselves acting in that capacity. The concrete blocks are threaded over the vertical rods and allowed

to glide into position. In addition to the "ties" used, further strength and continuity is gained by having the concrete blocks so made as to dovetail one with another. The iron or steel used in this work is of such forms that there is no need for any finished or skilled labour.

Some engineers entertain doubts as to the duration of iron under water. The following extract from a paper appended to the Report of Harbour Commission should suffice to set their minds at ease.

"We are told that the *Mary Rose* was capsized when under sail at Spithead in 1545, and recovered in 1837, after having been under water 292 years. It was then found that the guns, which were of the ancient type of wrought iron bars bound together with iron hoops, having detached chambers keyed into solid wood, are corroded to the depth of a quarter of an inch."

Now, as the iron rods used in the construction of a breakwater on the Lewthwaite plan would be about 2½ inches in diameter, it would at this rate take over 1000 years to wear them away, a very fair period for a breakwater to stand. But long before that distant epoch was reached the constant movement of the ceaseless ocean would have thoroughly solidified the rock fillings into a gigantic monolith, which would stand for yet another thousand years.

In conclusion, the author begs to say that the object for which this paper has been written will be fulfilled if it proves the means of introducing to his professional brethren a method of successfully making breakwaters, piers, and sea-walls, with an upright wall in any position however exposed, and on any bottom, and thereby to overcome difficulties which in the past have successfully challenged the skill of the most eminent in the profession.

DISCUSSION.

The PRESIDENT said that the necessities of the insular position of England compelled Englishmen to take great interest in all that related to harbours and breakwaters. The possession of the largest navy in the world, and eight million tons of merchant shipping, made it imperative that efficient harbour accommodation should be provided. More harbours of refuge were wanted, but the cost of construction was the great difficulty in the way of providing them. Whether the new system which the author advocated would be a success still remained to be seen. Before calling upon their Past-President, Mr. Walmisley, Harbour Engineer of Dover, to open the discussion, he would propose a hearty vote of thanks to

Mr. Cheesewright for his paper; and this motion being put to the meeting, was unanimously passed.

Mr. A. T. Walmisley said they must admit that while the model of the very ingenious method of construction, described in the latter part of the paper, appeared to work admirably, it would be expedient to see a practical trial of the system actually made in the open sea, before they could speak positively about it. The historical sketch contained in the paper, and the diagrams, enabling them to compare one system with another, were exceedingly valuable. He was glad to hear Mr. Cheesewright allude favourably to the Tyne works. The stone apron shown upon each side of the section of those works was an admirable feature. At Tynemouth the contractors had some excellent plant, especially in the mammoth cranes which they employed. The improvement of contractors' plant was a great point to be borne in mind in the construction of breakwaters. Good plant economised the time of construction and reduced the cost. Upon one point he must enter the arena of argument with the author. He referred to the statement in the printed abstract of the paper that a harbour of refuge at Dover had defied the ingenuity of the greatest experts in breakwater construction. The author, himself, had in his paper mentioned several schemes which eminent engineers had put forward, and he (Mr. Walmisley) was in a position to say that the harbour of refuge had not defied the ingenuity of a great many experts. The work had been delayed, but it had not been abandoned by the Government. Only a short time ago, the member for Dover stated in public that the Government had not abandoned the idea of constructing a national harbour at that port. Those persons who believed that trade was more beneficial to the town than visitors, hoped to see a good harbour of refuge constructed there; but those who preferred visitors to national commerce supported the scheme for a promenade pier within the bay. The question, however, was more than a local one. It was one of national and imperial concern. There was no doubt of the merit of a vertical wall, if shipping came up against a breakwater or pier, but one of the most essential points to bear in mind was the width of construction.

Mr. L. F. Vernon-Harcourt said that he did not agree with the author in his objection to all the principles that had hitherto been carried out. It seemed hardly fair to say that no system had been successful up to the present time. He believed that the author stated at the beginning of his paper that the *pierres perdues* system was the only system which had been adopted. That statement could hardly stand in the face of the piers at Dover and at Wicklow, neither of which was on that

system. The breakwater at Aberdeen was not on the *pierres perdues* system, though apparently it had suffered from the sea. The author should also qualify his statement that none of the breakwaters had been completed within the lifetime of the engineers who designed them. One of the works, of which the author had given a sketch, namely, that at Alexandria, was constructed in two years. That would make the life of the engineer of very limited duration. There were many others which had not taken long in construction. Among these were the breakwater at Colombo, and one at Mormugao, on the Portuguese coast of India. With regard to the breakwater at Alderney, he (Mr. Vernon-Harcourt) was, for two years, resident engineer of that work, and the length of the breakwater was 4700 feet, not 4380 feet; and a paper which he read at the Institution of Civil Engineers in 1873 gave full details of the work.* That breakwater had naturally excited a great deal of criticism. Out of due regard to the memory of engineers who had passed away, it must be borne in mind that it was not entirely their fault that the Alderney breakwater was not as successful as it ought to have been. Mr. Walker, and afterwards Messrs. Walker, Burgess & Cooper, were the engineers who were responsible for the designs of the Alderney breakwater. They began the harbour upon a very small scale, and they were led by successive First Lords of the Admiralty, to increase the length, so that the breakwater, which was to have terminated in a moderate depth of water, was eventually extended into a depth of about 134 feet at low water. That was a depth which had not been equalled by any breakwater in the world, and the work was exposed to the whole force of the Atlantic gales, and fronted the north-west, which was the direction from which the worst winds of that part blew. No doubt there were mistakes made in that breakwater, but nevertheless, the system was on its trial at the time. Another breakwater which was under his control for a time, namely, that at St. Catherine's, Jersey, stood in a more sheltered position, and though much less solidly constructed, had stood perfectly, except near the top, consisting of masonry laid without mortar. Therefore the site of the Alderney breakwater had more to do with its non-success than the design. The St. Catherine's breakwater was completed in nine years after its commencement. He had never heard it proposed that the breakwater at Alderney should be blown up, though he had heard, within the last few weeks, that the Government purposed ceasing to do any further work of maintenance on the breakwater, and therefore it would go to ruin in time. As to

* 'Minutes of Proceedings, Inst. C.E.,' vol. xxxvii. p. 60, and plates 2 to 7.

the Dover breakwater, he could not admit that it had a rubble base; it was founded on solid chalk.

Mr. Cheesewright said that the paper did not state the base to be of rubble,* and the diagram in fact showed it to be of chalk.

Mr. Vernon-Harcourt said that the Tyne breakwater appeared to have taken a very long time to construct, but it must be recollected that no attempt was made to carry the work out rapidly, and the piers were merely extended in proportion to the funds available. The compression of the air, mentioned in connection with the breakwater at Aberdeen, was a very important matter; and it was the cause of considerable damage to breakwaters when fissures or cavities existed in them. At Alderney there were fissures just about low water mark; and during a storm, the waves receded for a minute, then dashing against the breakwater, compressed the air within the fissures, and caused the face stones to be forced outwards upon the sea slope. Of course the endeavour of the engineer was to make a breakwater as solid as possible. Wicklow was alleged in the paper to be the first instance of the construction of a breakwater with concrete *in situ.* That was a very satisfactory breakwater, but it was not the first instance in which concrete was so deposited, if one might take the case of concrete deposited within timber frames. At a breakwater in Ireland, on which he was engaged for some time, the work was carried out with concrete, deposited *in situ* within frames. That system seemed to be a good one. Last year he carried out a small work, very cheaply, by that means, and using also a certain proportion of large stones in the work. It was a pier of 123 feet in length, extending to 12 feet below low water on the sea coast. The work was executed in six months at the comparatively small cost of 41*l.* a lineal yard. He did not agree with the author that Dover and Plymouth had the same exposure. The two exposures appeared from the charts to be totally different as regarded "fetch" and depth in front, Dover being very much less exposed than Plymouth. He believed that the real reason why the Dover pier had not been extended further was that Government had not seen fit to provide the money for its prolongation. It was one of the works which it was thought might be carried out by convict labour; but Peterhead had been preferred for the present. It was quite possible that when Peterhead was completed, Dover would be recommenced. There was no reason why, if sufficient funds were granted, the work could not be carried out. As to the system which the author had described and illustrated, it was very difficult to deal with

* Chalk. See author's reply, p. 113.

it as it was a comparative novelty. Engineers always liked to see a novel system tried, not by themselves, but at the expense of somebody else before adopting it, and it was very difficult to determine what merits or defects the proposed system might possess until it had been carried out in actual practice. One point of difficulty seemed to be in laying the foundation courses. The blocks would not be horizontal on an irregular bottom; and, if he was not mistaken, the author proposed to fill the interior of the breakwater with rubble stone thrown in at random, or with sand. It was possible that concrete blocks, strong or vertical iron rods, and tied horizontally by iron straps, might afford a more expeditious and firmer casing than a framing of timber work, though probably much more costly; but whatever the skin was, he was convinced that the interior must be filled with concrete in mass, and that the whole thing should be solid from beginning to end. No period of time would convert the *pierres perdues*, or sand filling, into a solid mass; and however solid the casing, the whole structure would fall to pieces as soon as the iron work was considerably weakened by rust. Therefore he thought it was a mere choice between using these concrete blocks as a skin, and the frame work of timber by which engineers protected concrete when deposited *in situ*, and which was afterwards taken away. As it was impossible, in his opinion, to regard the system as a means of permanently and solidly enclosing a mass of loose filling, which, in the case of sand, would be readily washed through the joints of the blocks, the claims urged for the system of great economy, rapidity of construction, and durability, as compared with the systems in use for the construction of breakwaters, appeared illusory. Before asserting such claims for any system, it should be submitted to the test of actual construction in an exposed site, by which the value of such claims could be practically determined. Any system of breakwater construction, really possessing the great advantages claimed for the system described, would, after due trial, be certain to be largely adopted.

Mr. W. R. Kinipple remarked that the paper recalled to his mind two lectures he had delivered, one on the 6th and the other on the 14th of March of last year, before the officers of Royal Engineers at Chatham in which he had described some of the breakwaters constructed during the present century, and more especially that which he had recently completed, namely, the Hermitage breakwater in Jersey, which had an average height of 61 feet, a maximum height of 66 feet, and was founded on a base 50 feet in width, by a few feet in depth. This base formed of rubble and shingle, which filled up the irregularities in the

rocky bottom, was grouted up solid with thick Portland cement grout, and the surface struck off perfectly level. On this levelled surface was founded the vertical wall of about 60 feet in height, by 42 feet in width. The whole of the concrete blocks both above and below low-water level had flat tongues and wide grooves on all unexposed faces, and were cemented together into a perfect monolith from foundation to cope. In section this breakwater differs very little from that at Dover, except that its sides are perfectly vertical, while those at Dover have a considerable batter. Roughly speaking, the Hermitage breakwater, faced with granite, was executed at 100*l.* per foot run, or less than one-third of the cost of that at Dover, and at a rate of about two and a half times as fast. He ventured to state that the Hermitage breakwater embodied most, if not the whole of the essentials, Mr. Cheesewright considers necessary to meet his views of the beau-ideal of a perfect breakwater. Mr. Kinipple stated that a length of 2100 feet of quay wall in the haven of Yarmouth was now being constructed on this system under himself as chief engineer, and Mr. Cockrill, the borough engineer, as resident engineer. The Lewthwaite system, which Mr. Cheesewright is now so strongly advocating, may bring about similar results; but he, Mr. Kinipple, had designed an exactly similar system twenty-five years ago, and had abandoned it on account of its great cost, difficulty of execution, and the fact that its life would have practically depended upon wrought-iron ties; and, therefore, could not have been regarded by engineers as a satisfactory and permanent public work, for wherever wrought-iron rods or ties are exposed to the action of the sea, between wind and water, oxidation rapidly sets in. It is true, however, that chains and anchors which have been raised from depths of more than 20 feet have been found, owing to their having been coated with a film of deposit, to be in a tolerably good state of preservation after centuries of submersion. If Mr. Cheesewright will turn up Mr. John Grant's paper on the Strength of Cement, in the Minutes of the Institution of Civil Engineers, Session 1865–66, vol. 24, p. 127, he may there read remarks made by Mr. Kinipple as follows, viz.:—"Model No. 5 showed blocks of concrete coated with compo in the same way as the specimen blocks, guided into position by rods, or chains, built on a concrete foundation, the face joints caulked with cement or soft wood wedges, and the chains or rods grouted in with neat cement." He, Mr. Kinipple, had also, some seventeen years ago, prepared designs for quays and jetties proposed to be erected on the Greenock side of Gourock Bay, on the Clyde, which quays consisted of hollow piers or caissons of about

30 to 40 feet in height, and 20 to 30 feet square, were proposed to be built exactly as described by Mr. Cheesewright, and is illustrated by the models now on the table. The blocks, if Mr. Kinipple remembered rightly, were to have been 6 feet by 4 feet, by 3 feet in height, with two guide-rod holes in each block, and were to have been so threaded on the rods, as to break bond or joint with each other, and to have had level beds. All the joints on the outer faces were to have been caulked, and the whole structure grouted up with a thick paste of neat Portland cement, while the hearting was to have been composed of large blocks of rubble stone and shingle, also grouted up solid. The model of these quays is still in the Harbour Engineer's office at Greenock. He, Mr. Kinipple, was not aware that any engineer but himself, prior to 1865, had proposed to make blocks of Portland cement concrete, to guide them into position by iron rods, and to grout up their beds and joints through the rod holes with neat cement. Mr. Lewthwaites's patent is dated 29th October, 1887, and is for structures similar to those he, Mr. Kinipple, had designed more than twenty-five years ago. Again, if Mr. Cheesewright will look at Mr. Kinipple's patent, dated 5th October, 1881, he will see illustrated on drawings Nos. 5 and 6, Figs. 12, 13 and 14, a similar system of guide rods or piles, held in position by distance links or bars, and planks with loops on their faces, instead of blocks of concrete, so arranged as to be threaded on to the guide rods, and to form a mould for the reception of a hearting, or body of concrete to be deposited *in situ*, and on page 5 of that patent specification this system is also described; but as Mr. Kinipple had proposed the same arrangements fifteen years prior to the date of the patent, he did not patent it or claim it as original.

He, Mr. Kinipple, had great respect for veneering, especially if it was composed of granite ashlar set in and built up with the concrete block. He had used extra strong small concrete blocks in salt water, creosoted fir in fresh water, and greenheart in salt water for facing up, or making a mould for the reception of concrete *in situ*. As to depositing concrete *in situ* under water, he had done it for about 30 years, very extensively at Quebec some 14 years ago, and also in several harbour works on the coast of Scotland and elsewhere: and from his experience he might tell Mr. Vernon-Harcourt, who had just described a work he had recently completed with concrete *in situ*, that he, Mr. Kinipple, had not much faith in work so executed, especially in salt water, and therefore had altogether abandoned the system in favour of concrete blocks faced with ashlar on all exposed faces, and having the whole of the inner or unexposed

faces flat grooved, and tongued, and all the vertical and bed joints run up solid with thick neat cement paste or grout. It was only to-day he had heard that the concrete *in situ*, in the north pier at Girvan, from a few feet above to a few feet below low water, or down to the full depth of the foundation, was still gradually softening and wasting away, involving considerable annual cost for repairs, even although it was composed of four parts of fine shingle and coarse sand to one of cement, and was mixed in the usual manner, and deposited fresh into the frames of about 16 feet in height. The portion above high-water mark is still exceedingly hard and in a very satisfactory condition, but from high water down to the foundation it gradually becomes softer until the foundation is reached, where it is crumbling away like garden mould. The whole of this concrete was mixed in the same manner, of the same proportions, by the same men, and brought up to coping level in advance of the rising tide, so that none of it passed through water, and yet, with every care that could be possibly taken, has proved to be anything but satisfactory. The same thing occurred in Jersey under Sir John Coode, where a large number of 70 to 90-ton concrete blocks made in frames at about half-tide level, prior to 1877 for use in the Hermitage breakwater, had, after lying in the harbour for ten years, become so deteriorated that they had to be broken up, and the débris was used for backing up the new north quay. Mr. Cheesewright apparently does not seem to appreciate the works of the eminent harbour engineers of the past, and while condemning their works he has, in Mr. Kinipple's opinion, said rather too much in favour of Mr. Lewthwaite's system, which has not yet been put to a practical test. Mr. Kinipple very much doubted whether a thin skin of concrete, of two or three feet in thickness, and of the great height proposed under this system would, even although held in position by rods and ties, stand the heavy blows of Atlantic seas without breaking up. He heartily agreed with Mr. Cheesewright as to dispensing with the usual yielding and unreliable rubble mounds in depths of water not exceeding 40 or 50 feet; and he further condemned the extensive use of concrete deposited *in situ* or by means of bags in salt water, from the fact that the recent failures and rapid deterioration of concrete so deposited sufficiently prove that work so executed cannot be regarded by harbour engineers as permanent or first-class; better by far to build vertical walls, even up to 60 or 70 feet in height, with say 9 and 12-ton blocks, having their beds and joints solidly grouted up from foundation to cope, for this class of work can now be done as well under as out of water, at much less than half the cost of the bonded dry block system used in the construction of

the breakwater at Dover, and in considerably less than half the time; and further, by this system an enormous saving can be effected in the cost of providing 100-ton lifting and depositing machinery, including the necessary rails, trucks, and everything else in proportion therewith. The lavish and wasteful expenditure on such heavy plant by some of the engineers of the present day is almost incomprehensible, and what for? simply to overcome, in a measure, the want of solidarity in the subaqueous structures hitherto built of dry blocks, and possessing more or less all the evils of open or dry joints, of which even 100-ton blocks can do no more than slightly reduce. It is a well-known fact that the measure of the strength of a breakwater so built is the weight of a single block to resist the force of the heaviest seas in any particular locality, for should the rubble foundation on which the dry blocks are laid subside locally, some of the blocks are immediately relieved of the weight of the superstructure, and set free to be worked on their beds by the sea until a block is dislodged, when others quickly follow and a dangerous breach soon follows. In the Hermitage breakwater the blocks weighed only from 9 to 12 tons, but the joints and beds throughout the structure are so grouted up as to form a monolith without a single open joint or crevice from foundation to cope; and thus a work has been constructed capable of resisting the heaviest possible Atlantic seas that can come against it with blocks averaging only 10½ tons weight. In the Lewthwaite system no such provision for grouting has been made, and there will be great difficulty in slipping or threading the blocks on to the guide rods, and in preparing a perfectly level and true bed from end to end of the work on which to found the blocks. If such a level bed be not provided the upper blocks will ride upon the ends or corners of those beneath, and splitting of the blocks be induced thereby.

When engaged at Wick in 1880–83, he, Mr. Kinipple, visited the ruins of the breakwater there several times, once in company with Sir Alexander M. Rendel, and it was truly remarkable to observe how those ruins had kept the general form they had assumed immediately after the destruction of the outer end of the breakwater in December, 1872. In discussing the cause of this failure with the late Mr. Thomas Stevenson, whom Mr. Kinipple used frequently to meet in Scotland, Mr. Stevenson seemed to be of the opinion that it would be quite impossible to construct at Wick a breakwater composed of dry blocks of concrete, for had not the sea overturned a block of 1300 tons, and therefore a mound of heavy concrete blocks, which the present ruins would seem to suggest, might, if well packed together, form a class of work easily constructed and main-

tained at a simple cost. There is no doubt a good deal of truth in what Mr. Stevenson then advocated, and also in the views he had expressed as to this class of construction in connection with the proposed breakwater at Peterhead in the evidence he gave on the 9th of November 1883 before a "Sub-Committee appointed to investigate the question of the most suitable place for a harbour of refuge on the east coast of Scotland" (p. 51 of the report published in 1884), and he, Mr. Kinipple, might add that many other engineers have held, and still hold, the same opinion; but to him such designs have more the appearance of abject despair than of originality. To reproduce facsimiles of the ruins of breakwaters of the past surely can only be regarded as a retrograde step in the science of subaqueous engineering. An 1890 harbour engineer must indeed be reduced to sad straits when he fells himself compelled to advise a Harbour Board or a Government to adopt such a design. Many of the troubles of harbour engineers are self imposed, and to the non-professional man it would almost appear as though some engineers took a joyous interest in battling with difficulties which they themselves had created.

Mr. Kinipple granted there was some truth in what Mr. Cheesewright had asserted as to the want of homogœniety in the works of the engineers of the past, but at the same time he must not forget that Portland cement, the friend of the modern engineer, was unknown when most of the works to which Mr. Cheesewright had referred were designed and carried out, and Mr. Cheesewright might rest assured that even the system he had so graphically described this evening will not suffice to set right in the future everything that had been wrong in the past. Mr. Cheesewright has referred to the Tyne piers, but even there the bonded dry block system had been used, except for the hearting, which was of Roman cement concrete *in situ*, and must, like all kindred structures founded on yielding rubble foundation, be liable to periodical damage. Although these works have been costly, probably next to Dover, they are the best yet constructed on the English coast. He, Mr. Kinipple, might mention that the lectures he gave before the Royal Engineers in 1889 will soon be published, and that members will then be able to read an account of some of the defects in works composed of concrete deposited *in situ* under water in the quays in New York, which were reported upon by General John Newton, U.S.A., in 1876, whom he, Mr. Kinipple, met in New York in 1881, when the General fully described the fallacy of having any faith whatever in concrete deposited *in situ* under water; but he, Mr. Kinipple, then ventured to assert that good work, with a sound facing, might be obtained by depositing a stiff

paste of partially set neat Portland cement against the faces of the moulds, into which a skilled diver could ram or force through it, up to the faces of the moulds, small dressed blocks of ashlar, or, in the absence of ashlar, blocks of concrete formed of one measure of coarse sand to one of neat Portland cement, provided also that fine concrete be deposited as a backing to the same by facing skips, leaving the bulk of the hearting to be filled up with ordinary concrete in the usual manner. Even although double or treble the quantity of cement per cubic yard were used for under water work as for out of water work, which would be a very costly precaution, he would still strongly advise the abandonment of the use of concrete *in situ* for all important subaqueous works, and the use in every case, where possible, of the grouted up concrete block system, which after an experience in connection with some of the best harbour works executed during a period of many years, Mr. Kinipple had found to be the most economical and reliable system yet introduced, for by it perfectly monolithic structures can be built from foundation to cope; and further, as an example of what may also be done by this system of grouting, he might mention the underpinning of the undermined portion of the Hermitage Breakwater, Jersey, which was built prior to 1877. The underpinning has been successfully accomplished within the last two years by shingle and broken stone, grouted up solid, with a thick paste of Portland cement. In conclusion, he remarked, never do under water any work which can be done out of water!

Mr. A. Manning said that he thought that Mr. Kinipple had underrated the durability of iron and steel between wind and water. At all events, he (Mr. Manning) had seen instances of wrought iron being practically sound after having been in use over forty years in sea water.

Mr. J. W. Wilson, Junr., referring to the subject of the corrosion of iron, said that it occurred to him while the paper was being read that the comparative shortness of the life of iron rods when exposed to the action of sea water was likely to be somewhat of an impediment to the durability of the system advocated in the paper. He could not clearly see his way to the thousand years which the author spoke of as the life of the breakwater. In the case of the iron guns which were instanced in the paper, as having been submerged for two hundred years, the amount of corrosion, namely, $\frac{1}{4}$-inch was certainly very small. Those persons who were accustomed to study these matters would remember that interesting experiments had been made by Mallet and others and the amount of corrosion which was found to have occurred in the case of cast iron, immersed in clear salt

water, was at the rate of only $\frac{1}{10}$ inch per century, which would be about $\frac{1}{4}$ inch in the time alluded to above. That, however, was the minimum amount, and they would certainly expect to find it greater in the case of wrought iron. He remembered an instance of some 7-inch wrought iron screw pile shafts which were put down upon the English coast, and which in a comparatively few years had decreased in diameter to 5 inches. Not many years ago he saw some hollow wrought iron columns being manufactured in the Midlands, intended for sea work in South America. They were made of $\frac{5}{8}$-inch plate, and were intended to replace some of the same dimensions sent out fourteen or fifteen years previously. The manager of the works said to him, "As manufacturers we do not suggest that the columns had better be made differently, because we look upon this as a standing job, and we expect in fourteen or fifteen years to have another order for a similar set." His (Mr. Wilson's) experience led him to the opinion, which he had always acted upon in practice, that when it was found necessary to employ wrought iron for sea work it should be made as solid and as durable as possible.

Mr. W. N. Colam said that he was anxious to ascertain from Mr. Cheesewright, whether it was not a fact that the Cherbourg superstructure was made of *bêton* cast in very large wooden frames with sides easily removed and with loose canvas bottoms adaptable to rugged foundations. He read about twenty years ago in the 'Proceedings' of the Institution of Civil Engineers a description of the work. Mr. Cheesewright had mentioned Cherbourg, therefore Mr. Colam should like to have some information on this subject, if possible. The new mode of construction which had been carefully described in the paper had certainly one very important feature which appeared to have been under-rated. It had been stated that very few drawings were required for carrying out the work, and he thought thas Mr. Cheesewright could scarcely mean that those drawings which had been shown, were all the working drawings that were required. He had been very much interested in hearing that the annual cost of the up-keep of the Dover structure amounted to nothing. He presumed that that was only a figure of speech.

Mr. F. H. Cheesewright, in reply, said that he found on reference that the paper did state that the Dover breakwater was founded on rubble; this, however, was due to a purely clerical error. Mr. Harcourt had pointed out some instances in which breakwaters had been completed in the lifetime of thir engineers. The remark contained in the paper upon that subject was a quotation made by the chairman of the Select

Committee before which Sir John Coode and other engineers gave evidence. And notwithstanding what Mr. Harcourt had said, he maintained that in most cases the engineers had not lived until the works were finished. He was referring only to those structures which were looked upon as monuments of engineering skill, such as those at Portland, Alderney, Plymouth, Holyhead, and Cherbourg. A question had been raised as to the means of dealing with a case in which there was an irregular bottom. This was shown in Fig. 15. First of all bags of concrete were deposited and then heavy concrete blocks were laid on the top. Mr. Kinniple had stated that he referred to the system now described in the years 1865 and 1866. The invention, however, dated a long way farther back than that. The *Taranaki News* of the 19th November, 1857, published a paper on "Breakwater and Improvements at New Plymouth, New Zealand," together with a plan in which the invention was described and illustrated by a plan by Mr. J. Lewthwaite. He would be pleased to show this to Mr. Kinniple. Some remarks had been made by Mr. Wilson with reference to the life of iron. He (Mr. Cheesewright) had, in his own professional career, erected five lighthouses upon screw piles. Fourteen years ago he built one in Australia the height of which was 114 feet from the foundation to the light. He had recently visited that structure and he had found that the corrosion of the iron piles might be regarded as nil. He was unable to say whether the government had had it scraped and painted every year. The piles were 8 inches in diameter and were made of solid wrought iron. An instance which anybody could see for themselves was that of a chain cable slipped by one of the Spanish vessels three hundred years ago off Tilbury. This was now at Windsor, and upon inspection he had found that the iron was perfect, simply being coated with a black corrosion which formed just a slight skin of the cable chain. Mr. Messent had shown him some cable that was taken up from the bottom of the Tyne, which had been badly corroded or worn out in ten or twelve years, but that was outside some chemical works where the iron had not had much chance; quality of course had a great deal to do with the life of iron as with every thing else. He believed that there was some possibility of Mr. Lewthwaite's system of construction being tried in a place where there was 30 feet of water and a 40 feet rise of tide. He had undertaken to erect a breakwater under those conditions and he thought that if it proved successful it would be regarded as a decided stride in advance in the science of engineering.

Fig 1 — FAMAGOUSTA. —

— SECTION OF ANCIENT MOLE. —

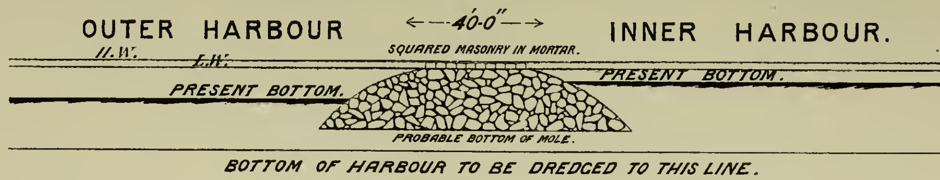
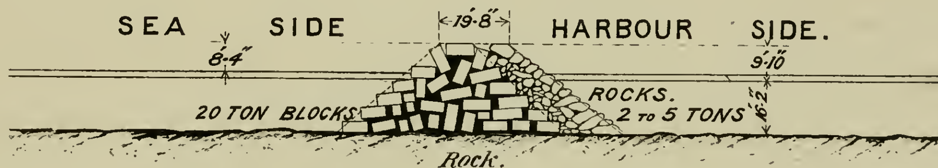


Fig 2 — ALEXANDRIA —

— SECTION OF BREAKWATER. —



d
y
t
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h

FIG 3

— MARSEILLES. —

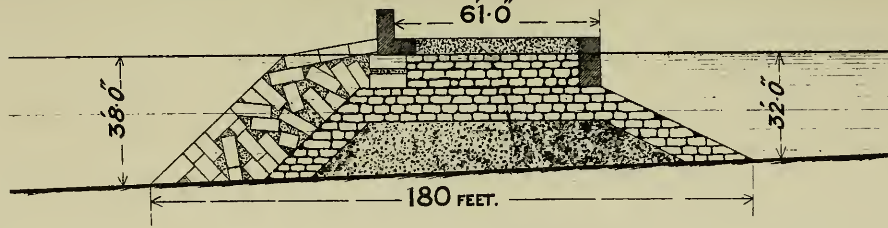
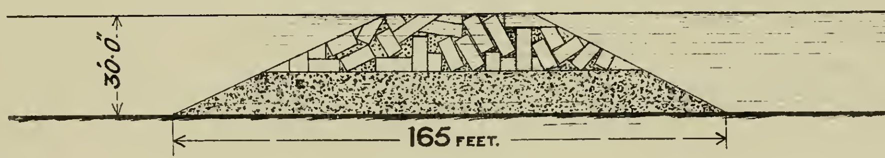


FIG 4

— ALGIERS. —



— SCALE 10 FEET = 1 INCH. —

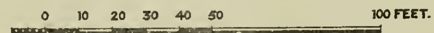


Fig 5

— PLYMOUTH. —

— SECTION OF BREAKWATER. —

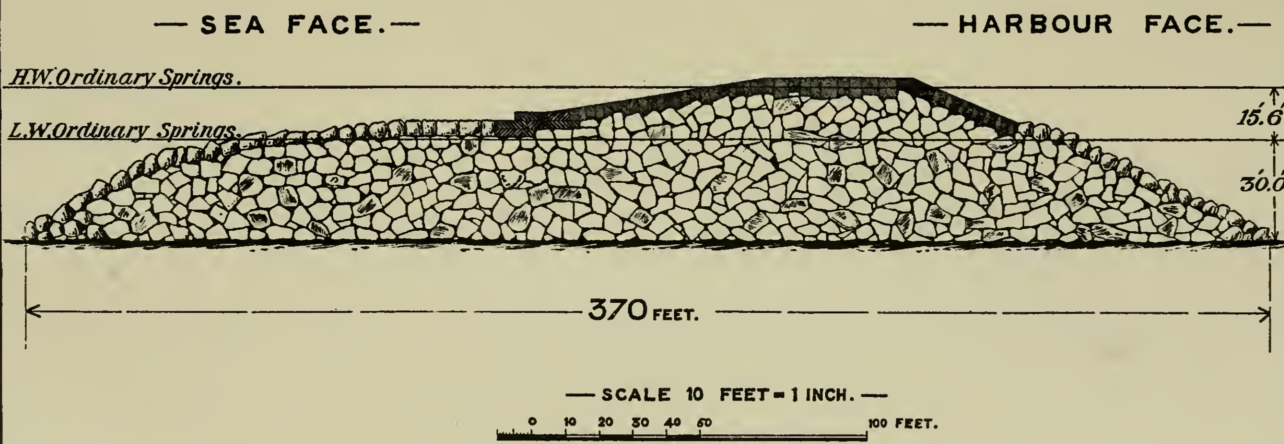


Fig 6

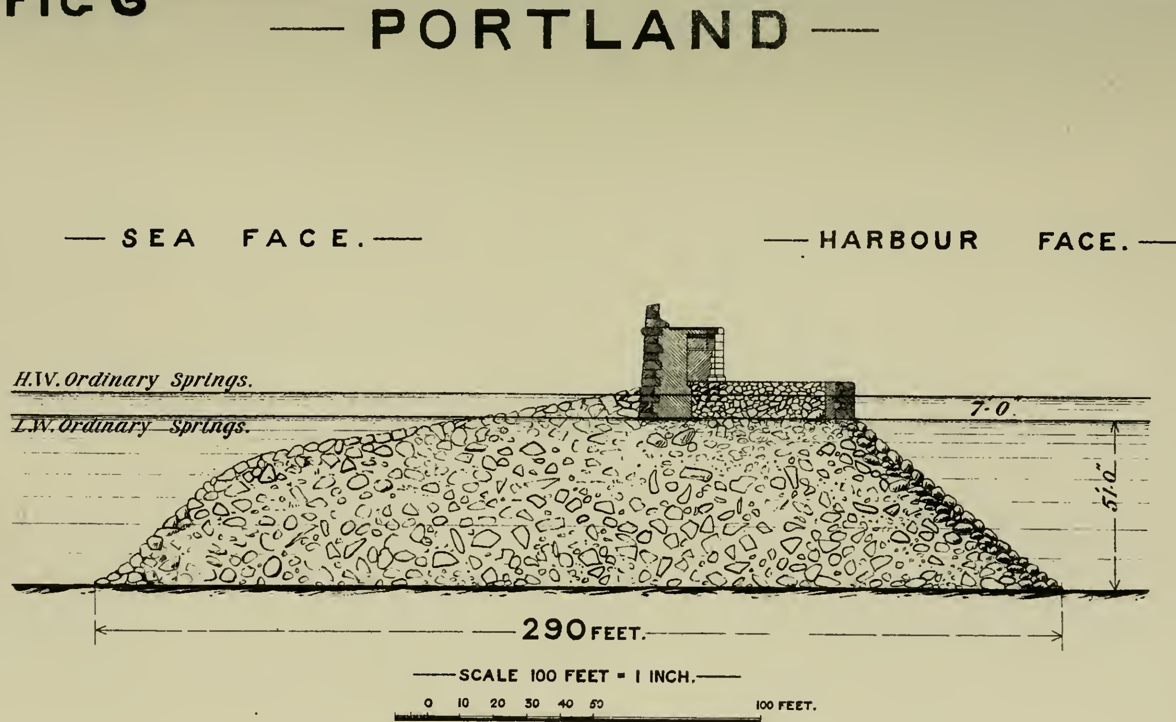

PORTLAND
SEA FACE.
HARBOUR FACE.
H.W. Ordinary Springs.
L.W. Ordinary Springs.
7·0"
51·0"
290 FEET.
SCALE 100 FEET = 1 INCH.
0 10 20 30 40 50
100 FEET.

Fig 7

— ALDERNEY. —

—CROSS SECTION OF WEST BREAKWATER.—

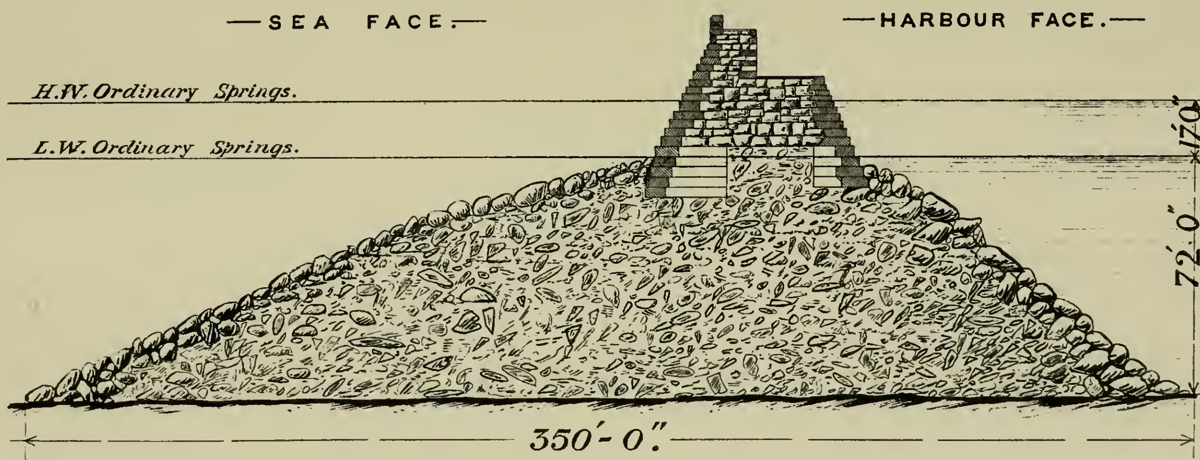


Fig 8

— DOVER. —

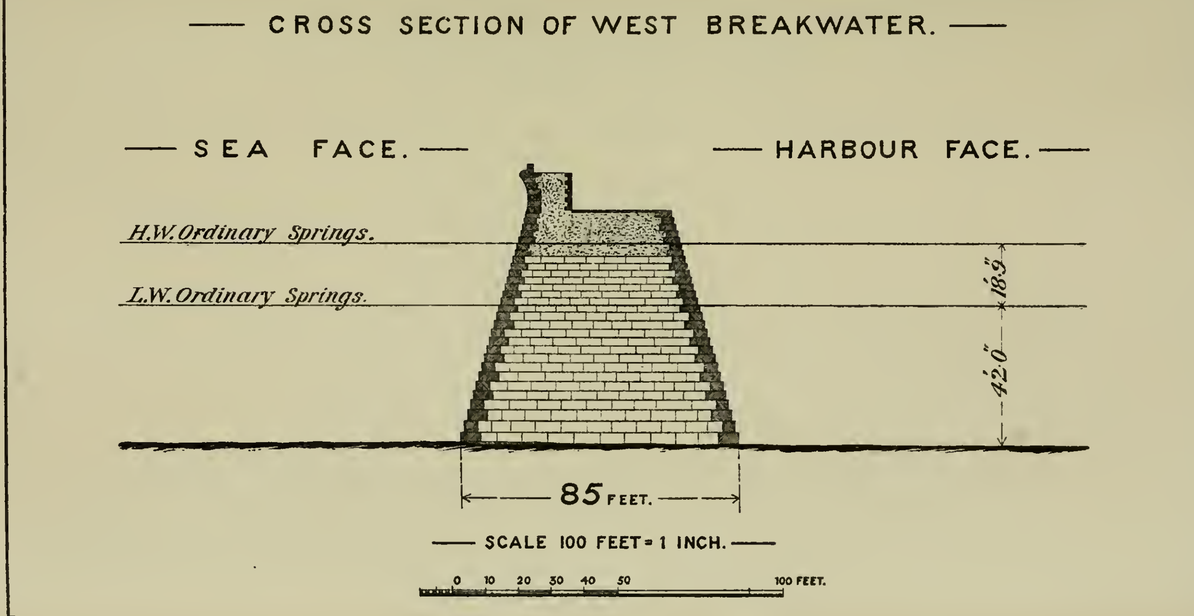

— CROSS SECTION OF WEST BREAKWATER. —
— SEA FACE. —
— HARBOUR FACE. —
H.W. Ordinary Springs.
L.W. Ordinary Springs.
18.9"
42.0"
85 FEET.
— SCALE 100 FEET = 1 INCH. —
0
10
20
30
40
50
100 FEET.

Fig 9

TYNE

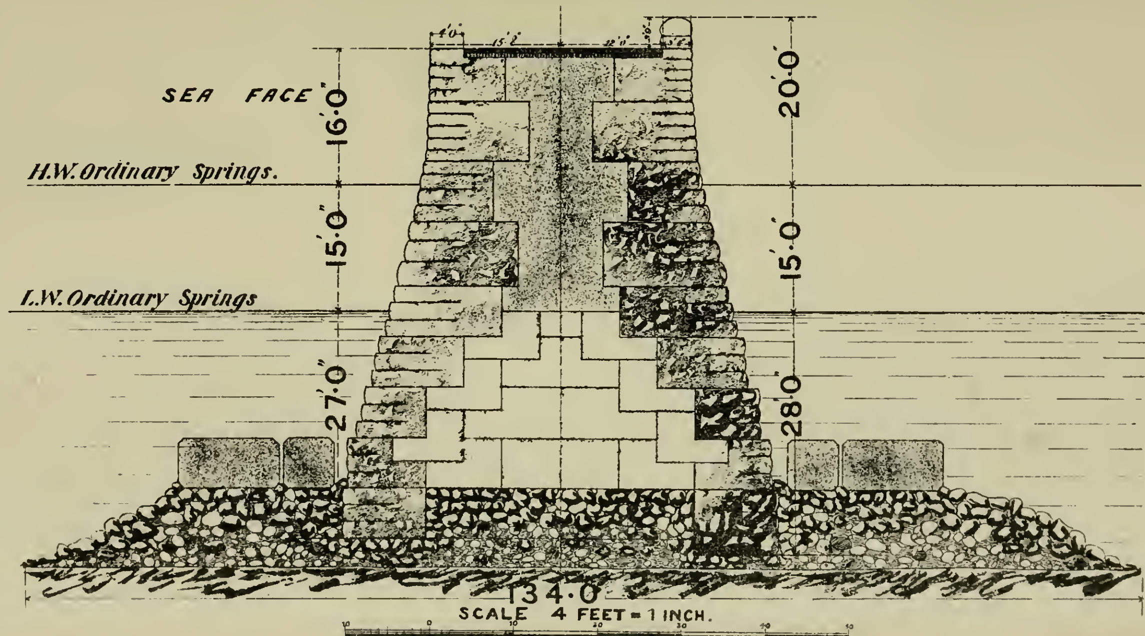

SEA FACE
H.W. Ordinary Springs.
L.W. Ordinary Springs
16'0"
15'0"
27'0"
20'0'
15'0'
28'0'
134.0
SCALE 4 FEET = 1 INCH.

Fig 10

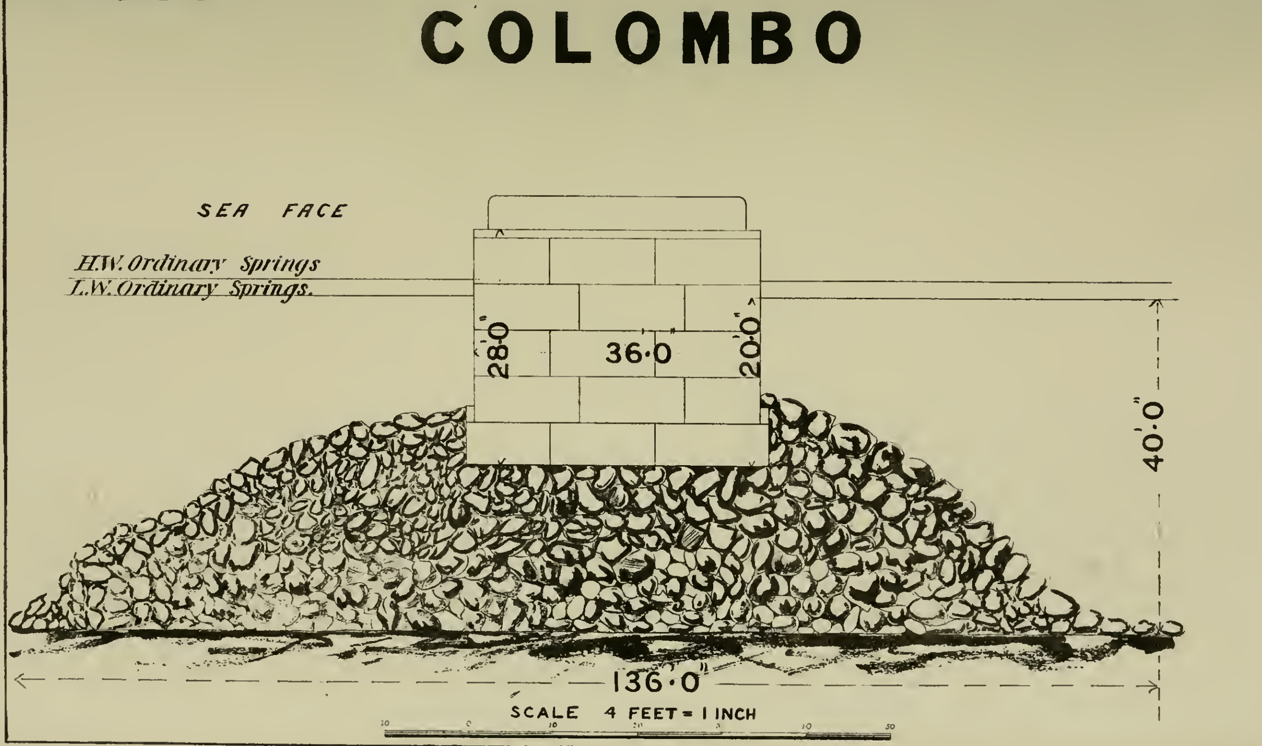

COLOMBO
SEA FACE
H.W. Ordinary Springs
L.W. Ordinary Springs.
28'0"
36'0"
20'0"
40'0"
136'0"
SCALE 4 FEET = 1 INCH

Fig II

CHERBOURG

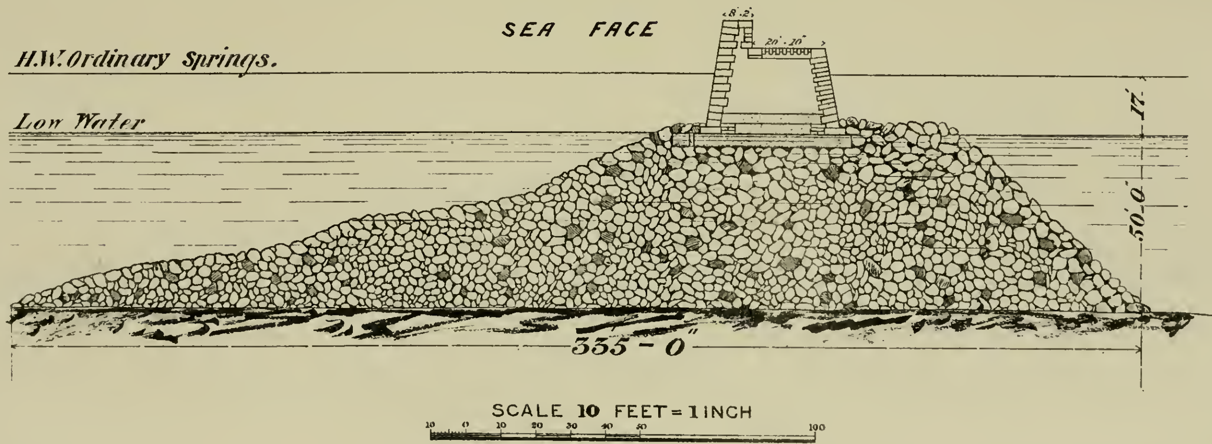


Fig 12

HOLYHEAD

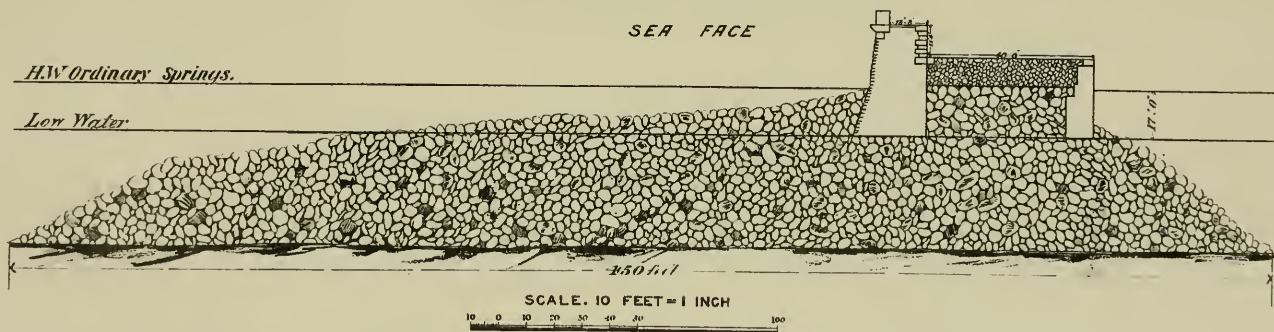


Fig 13

WICK

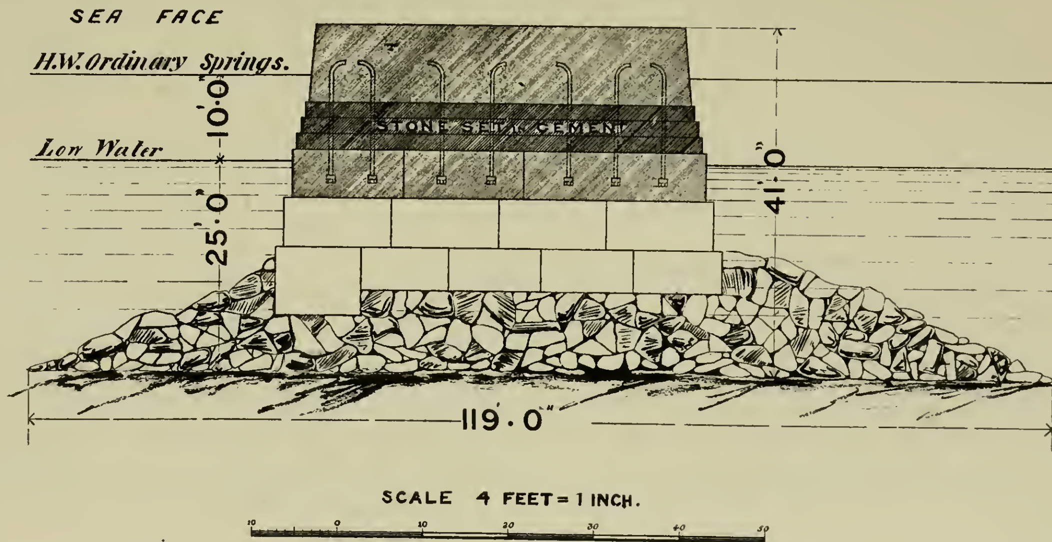

SEA FACE
H.W. Ordinary Springs.
Low Water
10'·0"
25'·0"
41'·0"
STONE SET IN CEMENT
119'·0"
SCALE 4 FEET = 1 INCH.
10
0
10
20
30
40
50

FIG 14

OPEN WORK SYSTEM FIXED ON AN UNEVEN ROCKY BOTTOM

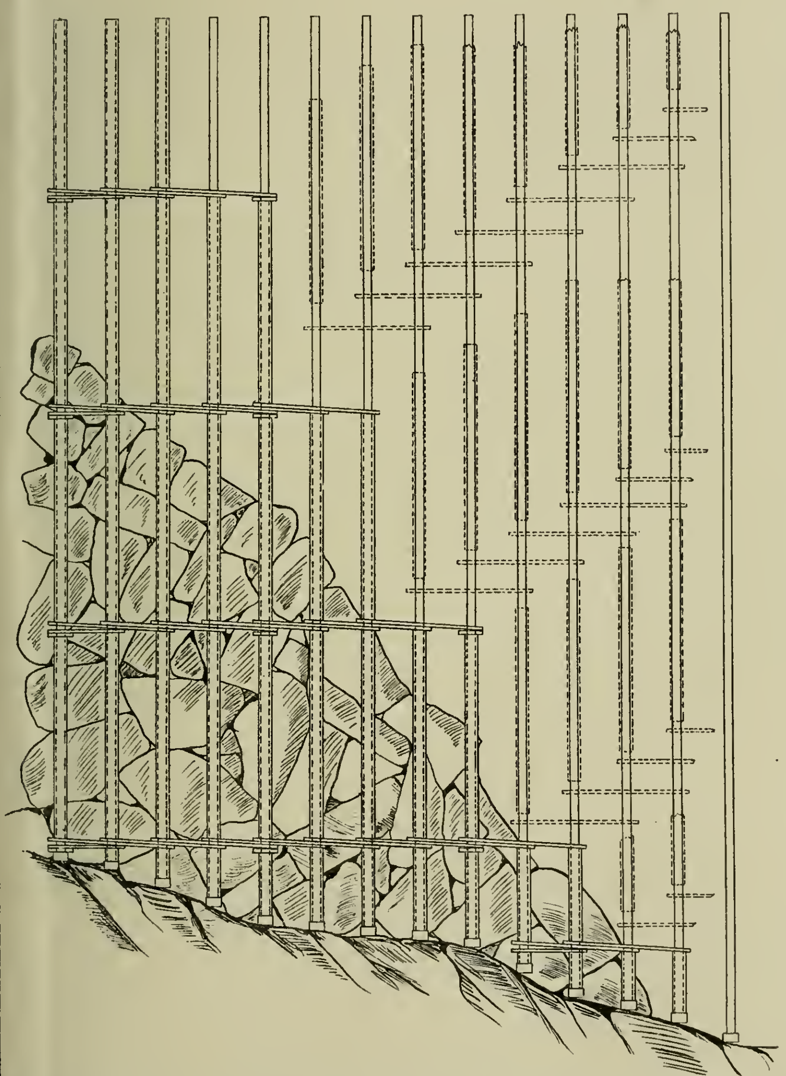


FIG. 15

METHOD OF ADAPTING THE CONCRETE BLOCKS ON AN UNEVEN ROCKY BOTTOM

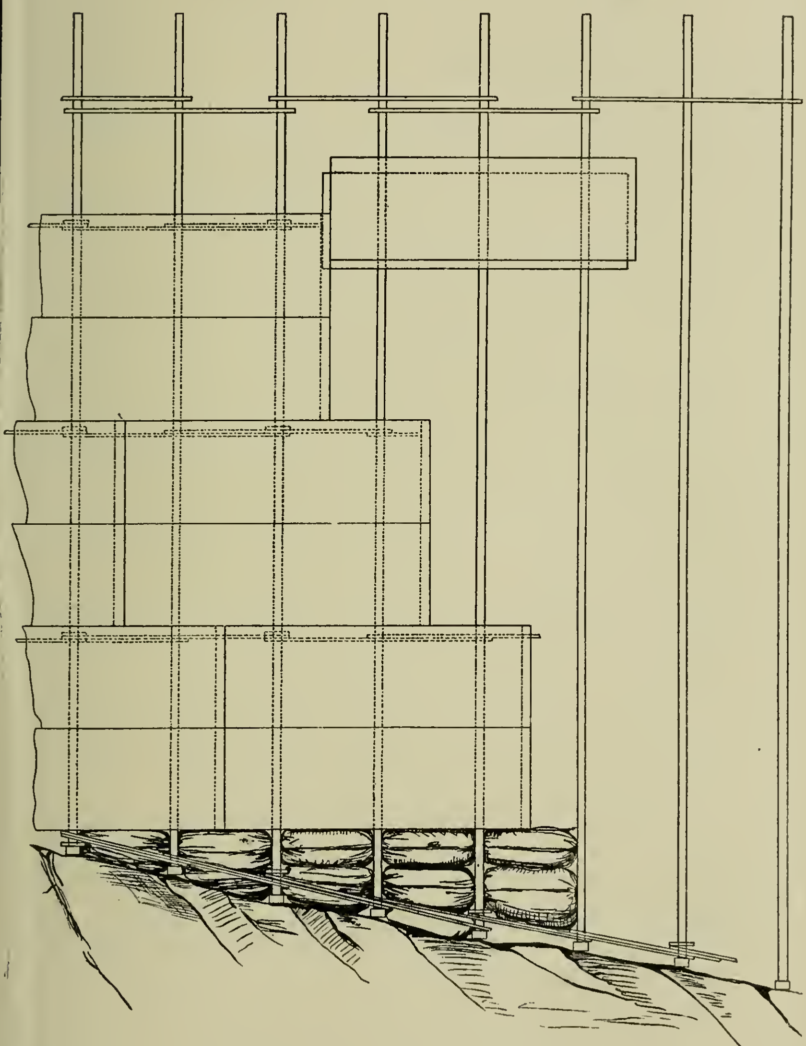


Fig 16

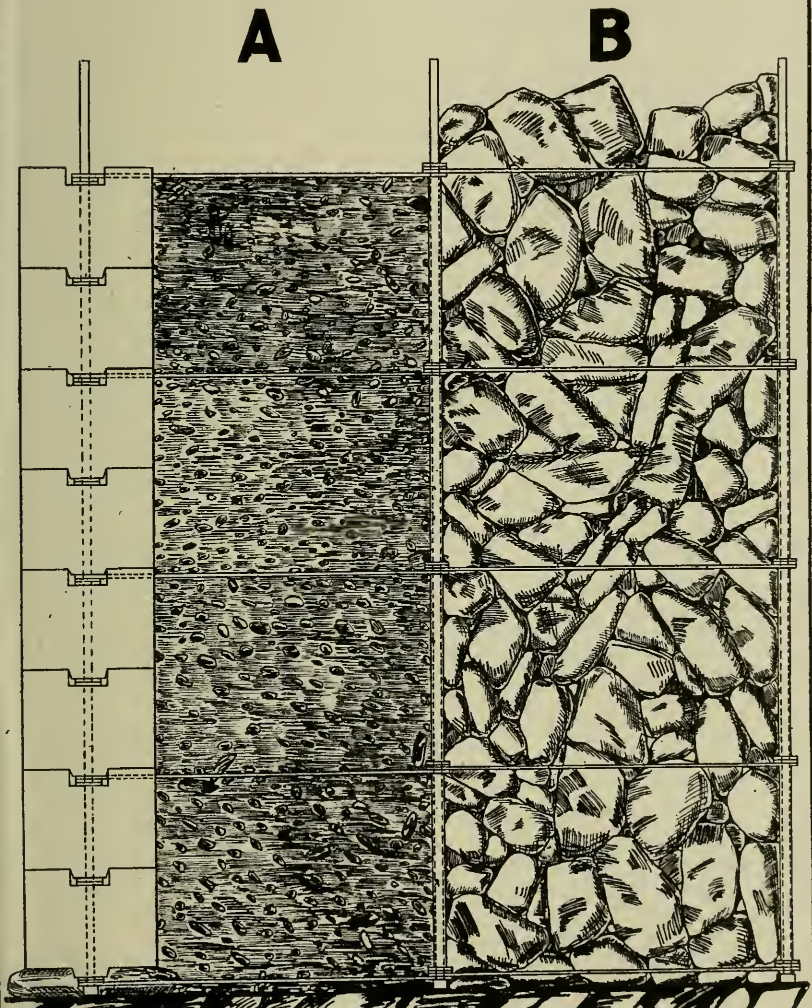


FIG 17

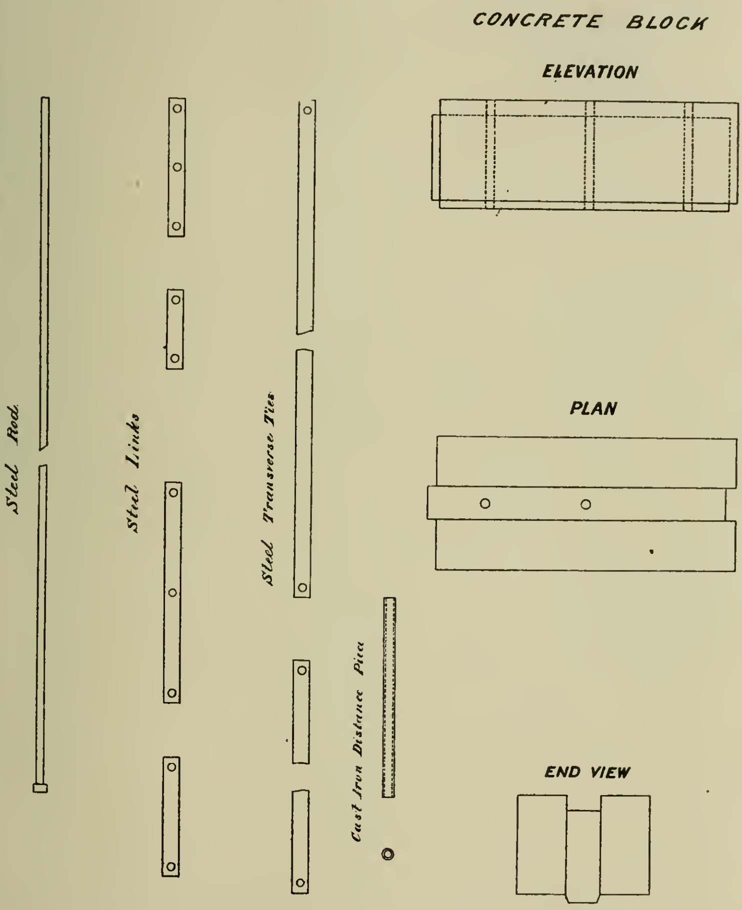
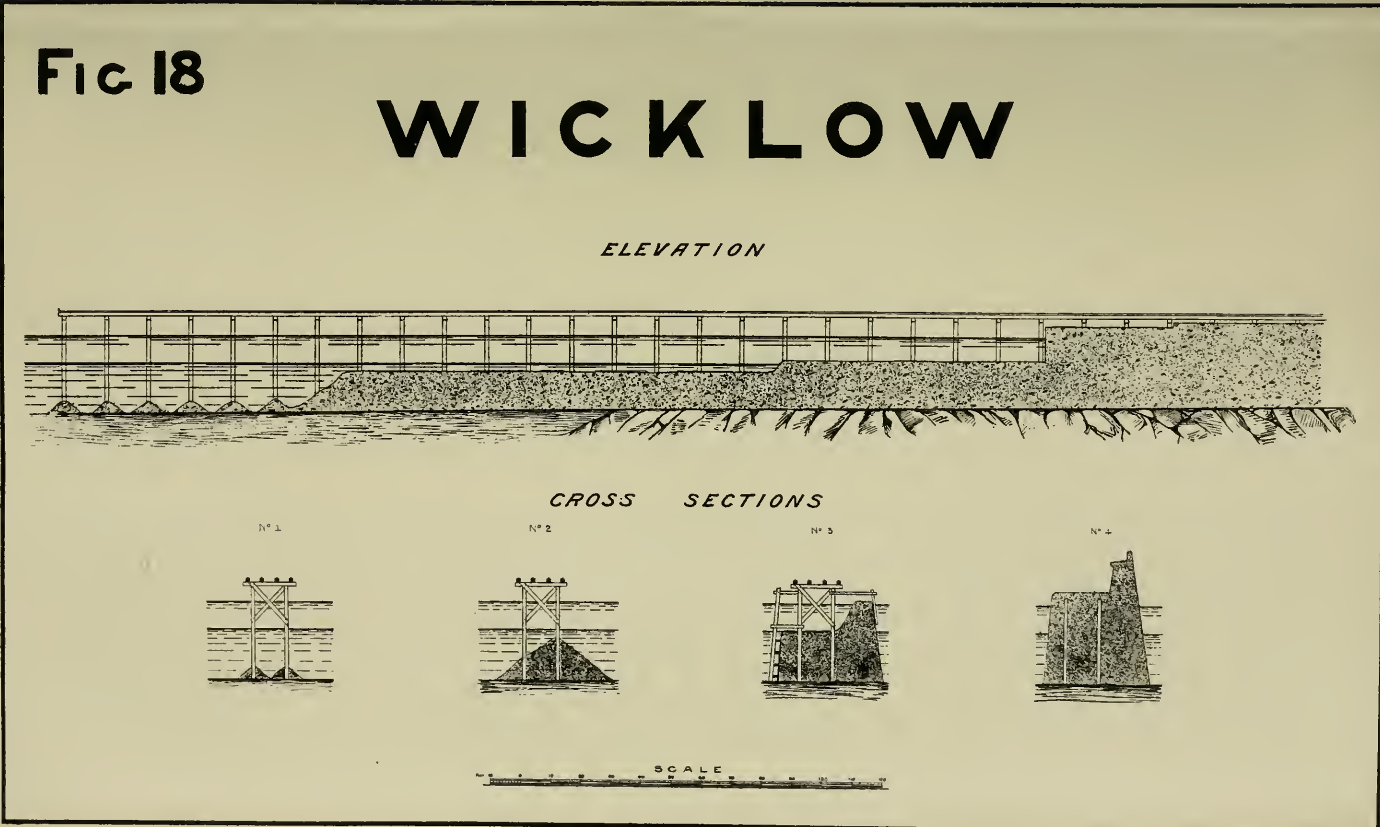

CONCRETE BLOCK
ELEVATION
PLAN
END VIEW
Steel Rod
Steel Links
Steel Transverse Ties
Cast Iron Distance Piece

Fig 18



June 2nd, 1890.

HENRY ADAMS, President, in the Chair.

PICK'S SYSTEM OF MANUFACTURING SALT IN VACUO.

By Perry F. Nursey, Past-President.

Introduction.

The subject of salt manufacture does not, perhaps, at first sight appear to be one which presents many points of interest to the engineer. That, however, is, if not the fault, at any rate the misfortune of that industry, which has been obliged, by force of circumstances, to drag on a tolerably monotonous and unchangeful existence for some centuries past. Not but what invention has always been more or less busy in this direction, as it has in others, but the practical results have been, so far as scientific progress is concerned, practically nil. Improvements have, of course, been proposed from time to time, but of these the bulk have shown themselves to be, on the face, utterly impracticable. Others have been submitted to the test of practical application, and have been found wanting, while a few improvements relating to one or other of the details of the antiquated open brine-pan system alone have survived the ordeal of working trial. The attempts which have been made to modify the ordinary pans and furnaces have at the best resulted in such a small increment of success as regards improved results of working, that it has long been evident that substantial improvement could only be the outcome of a radical and thorough change. This radical change has now been effected by Dr. Sigismund Pick, of Szczakowa, Austria, who has for many years past devoted his attention to the subject in connection with chemical manufactures, on which he is a high authority. This change having been made by means of special apparatus, the author conceives that the time has arrived when the manufacture of salt will be brought more absolutely and in a more pronounced manner within the domain of the engineer than it hitherto has been. Dr. Pick's system also marks a

scientific advance, and therefore appeals to scientific men, several of whom, of the highest reputation, have inspected the working of the system, and have stamped it with their approval.

Ordinary Process of Salt Manufacture.

Before proceeding to describe Dr. Pick's system, the author will briefly indicate the ordinary method of salt manufacture. And here he would observe that it is a remarkable fact that, notwithstanding the splendid advances which science has enabled almost all our other industries to make, she has hitherto failed to influence or promote in any material degree the manufacture of salt. Neither chemistry nor mechanics, nor the two combined, have been able practically to raise that important and widespread industry above the level at which our remote ancestors found and left it. The air of sweet simplicity which antiquity impressed upon salt making, appears to be still largely preserved to it, and the production of an important article of daily consumption by the whole human race is in the main left untrammelled and unfettered by any of the least of those scientific considerations which permeate all other industrial processes, including those of comparatively minor importance. Chloride of sodium, or common salt, occurs in nature chiefly in two forms, either as rock salt forming extensive deposits, or disseminated in minute quantities through the strata forming the earth's crust. Water penetrating the layers of rock salt and exerting there a solvent action, gives rise to brine springs. There are extensive rock-salt mines, and salt is in some places produced by dissolving the rock salt and evaporating the brine thus made. But the chief supply of salt is obtained from brine springs, and the production of white salt from brine is a very simple process. Salt being soluble almost equally in hot and cold water, it is only necessary to keep the brine boiling, and by this means to evaporate the water by which it is held in solution, the salt being precipitated in proportion as the water is driven off. The simplicity of the process is probably the reason why the improvements of modern engineering have not hitherto been brought seriously to bear upon it. Precisely the same method of manufacture is pursued all over the world. The brine is evaporated in open iron or steel pans of various shapes, usually rectangular, heated by open fires, and the precipitated salt is raked out, drained, and dried. As an example, the author will take the ordinary wrought-iron evaporating pans, which have an area of from 600 to 1000 superficial feet. Their usual form is that of an oblong square, and their depth ranges from 12 to

16 inches. There are three or more fires under each pan, and there is usually a separate pan-house to each pan—a salt works having any pretensions to a good output occupying a considerable area of ground. At one end of the pan-house is the coal store and the firing holes, while at the other is the chimney stack. Along each of the two sides is a walk, 5 or 6 feet wide, and between these walks and the walls of the pan-house long benches, 4 or 5 feet wide are fixed, on which the salt is placed in conical baskets to drain, after it has been taken out of the pan. In some pan-houses there are no benches, the salt being deposited on drainers on the floor. The house is covered in with a wooden or a slated roof, with openings for allowing the free exit of the steam. The fires under the pans are regulated according to the quality of the salt which is to be obtained. The finer the grain it is desired to give the salt, the more intense must be the heat applied.

Disadvantages.

The disadvantages of the ordinary system of salt-making are numerous as well as serious. In the first place, although the salt is raked out regularly, it is found impossible to keep the bottom plates of the pans quite free from it. This deposit, together with the salts of lime and magnesia present in the brine, however carefully the operations be conducted, forms a scale upon the plates which causes them to rapidly burn away and buckle or bend. Repairs are consequently constantly going on in salt works; and, indeed this item of maintenance is one of the most serious in a salt manufactory. The finer the salt produced, the heavier are the repairs, and the more frequently the pans require cleaning, the scale having to be frequently chipped by chisels from the plates, and damaged plates to be replaced by new ones. These pans cover a large area, and they can never be kept tight. The author has seen some of these broken down salt-pans under repair, and a more melancholy picture he has never beheld. He has seen rolling-mills which have stood for a week or two after a breakdown, and they looked dismal enough. He has been on board a fine steamer, the *Edith*, after she had been some months submerged in Holyhead harbour, and had just been raised, and she looked hopelessly wretched, but for a real genuine picture of downright desolation, he gives the palm to a disabled brine-pan. And it does not take long to disable them either, as may be imagined when it is stated that with the most careful working, and the best occasional patching, the life of a brine-pan cannot be put at more than about three years.

Besides repairs to the pans, there is another heavy item of expense in the manufacture of salt which has to be considered, and that is the fuel bill. In order to maintain the brine at the boiling-point, and to secure the proper rate of precipitation of the salt according to the quality required, a large consumption of fuel is necessary. There is yet another evil connected with the open pan system to which reference should be made, and that is the production of noxious gases, the effects of which are readily recognisable in the vicinity of salt works. As soon as scale begins to form in the pans the buckling action commences, the rivet seams open, and the brine leaks from the pans into the fire holes, producing gases which are alike deleterious to animal and vegetable life. To sum up, the ordinary process of salt making is slow and costly, and the output is comparatively small in proportion to the area occupied by the works and the quantity of fuel consumed. It is therefore not without satisfaction that the author is able to place before the Society, and through it the salt industry, an invention by which the cost of production is greatly reduced, the output largely increased, and, above all, the manufacture of salt successfully raised from a mere plodding process to a scientific system.

Dr. Pick's Process.

As already stated, this important innovation is due to Dr. Pick, whose process is simple, automatic, and continuous, and, whilst requiring only about two-fifths of the fuel at present necessary for the manufacture of salt, can be worked with a minimum of unskilled labour. Moreover, the apparatus being worked under vacuum, and heated by steam instead of by fire, the wear and tear is practically nil, whilst the products are of the highest quality, and the output exceptionally rapid and large. The secret of success lies in being able to materially quicken the process of production without risk of damage to the products and without increasing the absolute heat, but rather by reducing it, and at the same time reducing the expenses both of working and maintenance. The invention depends for its success upon two circumstances mainly. The first is that the boiling point of any liquid is lowered by reducing the pressure under which evaporation is carried on, and the second that the steam generated by the evaporation of any liquid contains a certain amount of latent heat which is sufficient to evaporate another quantity of liquid, provided the boiling point of the latter is below the temperature of the steam used. Dr. Pick, in fact, introduces into the salt industry principles similar to those upon which the Rillieux or triple

effect system depends, which system is, as is well known, in use for the evaporation of liquids in certain other manufactures. Attempts have been made to apply the principle of multiple evaporation to the manufacture of salt, but the fact that none of these attempts have hitherto succeeded in practice proves that there was something wanting in the apparatus. The missing link has been supplied by Dr. Pick in the vacuum filter which he has ingeniously engrafted upon the Rillieux apparatus.

The Apparatus.

As will be seen from the diagram, Dr. Pick's apparatus consists of three separate but duplicate sections, each section consisting of four main and closely connected parts. These are the boiling chamber A (Fig. 1), the heating chamber B, the collecting chamber C, and the filtering chamber D. The three sections are placed side by side a few feet apart, and they are connected together by pipes as shown. The heating chamber B of the first section is placed in communication with a steam boiler, or with the exhaust steam from an engine, by means of the pipe E. The boiling chamber A of the first section is placed in communication with the heating chamber B^1 of the second section by means of the pipe F, the boiling chamber A^1 communicating in its turn with the heating chamber B^2 of the third section by the pipe F^1. This latter section has its boiling chamber placed in communication with a jet condenser and air pump as shown. G is the brine inlet pipe to the various sections which is in communication with the brine tanks, the brine being raised by vacuum and supplied auto matically to the several sections. H is a pipe for automatically conducting the brine from the filtering chambers, D, D^1, and D^2, to the boiling chamber of each section, under the special conditions which will be explained when the author describes the modus operandi of Dr. Pick's system. J is a small pipe which connects the boiling chamber of the first and second sections with the condenser, and is used for assisting in maintaining a vacuum in each of those chambers. In like manner K is a small pipe for assisting the vacuum in the heating chambers of the second and third sections by clearing them of surplus air.

Details of Apparatus.

The boiling chamber of each section is simply a cast-iron cylinder, of larger diameter than the heating chamber beneath it. The object of the increased diameter is to enable the

chamber to contain a large quantity of brine with a minimum of depth and a maximum of evaporating surface. The usual level of the brine is seen in the first section, which in fact is a sectional view of a single apparatus, the second and third sections being shown in elevation. The heating chamber consists of a series of conical tubes of comparatively small diameter surrounding a central tube of larger diameter, as shown in the horizontal section at Fig. 2. The whole of the tubes are inserted in a tube plate at top and bottom, and enclosed in a cylindrical chamber, into which steam is admitted in the first section by the pipe E, and after imparting its heat to the brine is condensed, and passes away to a steam trap as shown. In the second and third sections, the condensed water is drawn off by pumps. The reason for having the tubes conical is to prevent scaling, or, should scaling take place, that it may be easily removed, the larger diameter of the tubes being at the bottom. The author's experience of the working of the system, however, leads him to believe that scaling will not take place, so moderate is the heat applied, so rapid the circulation of the brine, and so powerful the ebullition maintained. It is to promote and increase the rapidity of the circulation that the central enlarged tube is employed. In operation, the brine heated by the small tubes passes upwards through them to the boiling chamber. It then makes for the centre, and returns downwards through the large central tube by reason of the lower temperature prevailing within that tube. The proportion of the volume of brine to the heating surface being much greater in the large tube than in the smaller tubes causes a reduced temperature within it, and the rapidity of the circulation is thereby increased in accordance with the natural law that heated fluids or gases ascend while those of the lower temperature descend.

The settling chamber, immediately beneath the heating chamber, serves for collecting the salt as it is precipitated. It settles readily, as no movement takes place in the brine at that point. It is, of course, in direct communication with the upper or boiling chamber through the tubes of the heating chamber. This collecting chamber terminates in a sluice valve, and is in this way connected with the vacuum filter beneath it, which forms an important and essential feature of Dr. Pick's system. Each filter consists of an upper fixed portion and a lower hinged portion, the filtering medium being attached to the lower portion of the filter at its junction with the upper part. The upper part is fitted with an air inlet cock and a water pipe, ending in a rose for washing the salt if necessary. The lower

part of the filter is connected with the boiling chamber by a tube, the lower portion of which, as far up as the valve, is flexible, and yields when the filter is opened, as will be seen from the dotted lines in Fig. 1.

Method of Working.

The method of operating Dr. Pick's system is briefly as follows:—Each of the three sections having been charged with brine to the proper level, which is that indicated in the boiling chamber A, steam is admitted to the heating chamber of the first section, in which the highest temperature is maintained. The brine in that section becomes quickly heated, and the steam given off from that brine enters the heating chamber of the second section, heating the brine in that section. The steam given off from the brine in the first section, after doing its work in the heating chamber of the second section, condenses and produces a vacuum in the boiling chamber of the first section, which vacuum is aided, if necessary, by opening the valve on the connection with the vacuum pump. The pressure being reduced, the brine in the first chamber enters into violent ebullition at a comparatively low temperature. The same process is repeated in the second section, the steam chamber of the third section acting as a condenser, and producing a vacuum in the boiling chamber of the second section. The steam generated in the third section is drawn off by the vacuum pump, and condensed by the jet condenser as shown. It will be seen that the highest vacuum and the lowest temperature exist in the third section, while the highest temperature and the lowest vacuum occur in the first section. As the salt is precipitated it settles in the collecting chamber, and at stated intervals the sluice valve is opened and the salt and brine, are admitted into the filtering chamber. After settling there for a few seconds, the sluice valve is closed and the air-cock on the filter is opened. The valve on the ascension pipe H is then opened, and in a few seconds more the whole of the brine, in which the salt lies as in a bath, is automatically transferred to the vacuum chamber, leaving the charge of salt resting on the filtering medium and perfectly free from brine. The valve on the ascension pipe is then closed, the filter opened, and the charge withdrawn. The filter is then closed ready for another charge of salt.

It will be observed that during the operation of letting down the charge of salt and withdrawing it from the vacuum filter,

it is not necessary to stop working, the processes of evaporation and production being thus rendered simultaneous and continuous, and, above all, automatic. It was by devising this system of communication between the lower and the upper portions of each section that Dr. Pick was enabled to solve the problem of practically and profitably evaporating brine in vacuo. It is the vacuum filter that gives the finishing touch to the triple effect system in the present connection; and to Dr. Pick belongs the credit of being the first to succeed, by means of an ingenious but simple arrangement, in utilising the vacuum system for the manufacture of salt.

Working Results.

The author has hitherto been dealing with a complete apparatus consisting of three sections. The successful working of the Pick system, however, does not depend upon the use of three sections, inasmuch as the finest salt has been and is still being made equally well in one section, although of course not nearly so economically as if the complete set of three was adopted. In order to demonstrate the practical value of Dr. Pick's invention in England—for it had previously been proved in Austria—a single section, with its air pump and condenser, was erected in the early part of the present year at the Shirleywich Saltworks, Staffordshire, under the author's supervision. This plant has now been running for several months with thorough practical success as a salt producer. Steam is supplied to the heating chamber of the apparatus from an 8-horse portable engine, which also drives the vacuum pump and jet condenser. It is only a small plant, capable of turning out about 1 ton of salt per day of 24 hours from saturated brine, i. e. brine containing 2 lb. 6 oz. of salt per gallon, but this it does regularly. In fact, of late, and since the apparatus settled itself down into steady working order, it has on many occasions exceeded this output. A charge of salt weighing about 1 cwt. is drawn every hour without stopping the apparatus, and samples of the salt thus produced lie on the table for inspection. It will be seen that the salt is of the finest quality, and it is a noteworthy fact that the density of the salt produced by Dr. Pick's apparatus at Shirleywich is just double that of the salt produced at the same works and from the same brine by the ordinary open pan process. This will be seen from the samples, inasmuch as the 3-inch cubes of Pick's salt weigh 21 oz., whilst the 3-inch cubes of open pan salt weigh only $10\frac{1}{2}$ oz. or just half.

Cost of Production.

So far as the working of Dr. Pick's system, both in Austria and at Shirleywich, has gone, it has proved in all respects thoroughly satisfactory, and has amply demonstrated that the best and finest salt can be expeditiously and economically produced by it. Although it has not been possible in the special circumstances under which the apparatus was put up and worked, for the author to ascertain the cost of production, he is perfectly satisfied that, in practice, it will be very much less than that of the ordinary salt-pan system.

Advantages.

The practical advantages of Dr. Pick's system have, in the author's opinion, been fully established by the working of the apparatus at Shirleywich. It has shown (1) that a large saving of fuel is effected by it as against the ordinary salt-pan process. (2) That the space required for turning out a given quantity of salt is very considerably less than that required for an ordinary salt-pan plant capable of turning out a corresponding quantity. A plant capable of producing 50 tons per day will only occupy an area about equal to that covered by a salt-pan producing 40 tons per week. (3) That the cost of labour is reduced to a minimum, the apparatus being very simple in construction and practically automatic in action, and not requiring special supervision. (4) That the cost of maintenance will be very small, there being no plates to scale and burn out as in the ordinary salt-pan. With regard to scaling, the author would observe that he had the apparatus opened after several weeks' continuous working and found the tubes and all other internal parts bright and clean, and perfectly free from any sign of scale. (5) That as the brine nowhere comes in contact with fire, no acid vapours can be formed and given off as in the ordinary process, so that there is an entire absence of those noxious gases which are prejudicial alike to animal and vegetable life. The opinion of the author is that Dr. Pick has succeeded in effecting an important improvement in the manufacture of salt by means of a system which cannot fail to prove both economical and effective. These views are endorsed by practical saltmakers and by some of the leading scientific authorities on the subject. Sir Henry Roscoe, F.R.S., after inspecting the process, states in a report upon it that it is founded on sound scientific principles; that it is automatic and

continuous, and is a great improvement on the old process. Mr. Alfred E. Fletcher, H.M. Chief Inspector under the Alkali, &c., Works Regulation Act, who has officially inspected the apparatus at Shirleywich, states that Dr. Pick's system, if adopted for the manufacture of salt, will be a means of removing the great nuisance now arising from the emission of black smoke, and from the corrosive vapours now discharged so copiously from the fires under salt pans. He also observes, in his report, that the change of system will effect a great improvement in the condition of the workpeople employed. On these grounds he says he anticipates great public benefit from the introduction of the system.

Conclusion.

From the experience gained with the present limited plant, the author thinks he has fairly shown that Dr. Pick has succeeded in placing within the reach of the salt industry a factor which, by materially reducing the cost of production, must benefit the manufacturer and should in turn benefit the consumer. But this is not all. There is yet another and a broader aspect in which the new process may be viewed with advantage, and that is a national one. Notwithstanding the combination known as the Salt Union which was formed about two years since, the sale manufacture in England looks at present very much like a departing industry. In support of this statement the author may mention that whereas in 1888 there were 898,671 tons of salt shipped from this country, the shipments during 1889 fell to 666,796 tons, a decrease in one year of 231,875 tons, or, in other words, a loss of more than one-fourth of the export trade in salt. When it is remembered, too, that the exports of chemicals from this country, in the manufacture of which salt constitutes one of the principal items, stand at present at 2,000,000*l*. per annum, it becomes apparent that but for the introduction of Dr. Pick's process, or of some other equally efficient system, it may be expected that the decrease in the export of salt shown last year will be repeated, if not exceeded. The perfecting of his system has occupied Dr. Pick several years, and it seems as though he had brought his investigations to a practical issue at a very important juncture in the history of the salt industry. Let us hope that by the aid of the new process, England may regain and retain that which appears to be slipping from her grasp. Should it help to accomplish this it would materially add to the credit already due to Dr. Pick in respect of the present invention.

DISCUSSION.

The PRESIDENT said that the majority of the more important modern industries owed their success very largely to a combination of engineering with chemical knowledge. Mere handicraft skill was of minor importance compared with the immeasurable advantage which a scientific training gave to the engineer. The apparatus which had been described by the author showed, in a forcible manner, the value of this combined knowledge. He moved a very hearty vote of thanks to the author, more especially as from his position as a member of the Council, and a past President of the Society, he was debarred from receiving any other form of reward; and on this motion being put to the meeting it was passed unanimously.

Mr. ARTHUR RIGG said that the system which had been described was another illustration of mechanical contrivances applied to the improvement of a very primitive sort of manufacture, and it reminded him much of the change which had taken place recently in the manufacture of Portland cement. Originally fires were used for drying the cement very much like those used in the ordinary mode of salt making, and it seemed as if Mr. Nursey also meant that he used the exhaust steam from the engine to assist in the drying process. In that case a regular cycle was attained, and the system of drying at various temperatures seemed to add very much indeed to the regularity of the process. The arrangement seemed to be of extreme ingenuity, and one which it might be supposed from the theoretical considerations involved would work very well. Indeed it was somewhat akin to the principles employed in a regenerative furnace.

He observed that the salt produced was of very fine grain, but salt was now obtained of many sizes of grain, and there was a wonderful difference in the taste. The best tasting salt, so far as he knew, was the large grained salt mostly exported to India, and not sold much in this country. How the salt produced in the system now described in these very hard blocks tasted, he had no information. Salt was, perhaps, more uniformly distributed than any other substance in the whole world. In the Cheshire salt districts the towns were sinking down lower and lower. This was perhaps due to the gradual exhaustion of the salt and brine supply.

Whether the new apparatus would make the English salt industry as good as it used to be was difficult to say. The economy of the new apparatus seemed to be perfect, and the

whole thing, so far as could be judged from the description, made one wish to see it, because it was a very neat application of scientific knowledge and chemistry to an industry which evidently much needed improvement.

Mr. Howson said that he had not any great experience of evaporating brine, but at the present moment he was interested in any new machinery or improvements in connection with that subject. It was well known that fine-grained salt like that exhibited in the samples, however admirable it might be for culinary purposes, was unsuitable for many other purposes. How was large-grained salt to be produced by means of this apparatus? It appeared to him that the first section of it would produce the finest grain, and that the last would certainly produce a coarser grain, but salt of still larger grain than could be produced in Dr. Pick's apparatus was required in considerable quantity. He thought that the process would be of considerable value if Mr. Nursey could see his way to producing crystals of a sufficiently large size.

Mr. Macnab said that he had seen the small section of the apparatus working at Shirleywich, and it appeared to perform all that was claimed for it as far as one section could show. The main claim of the apparatus, however, was that it reduced the cost by something like two-thirds by utilizing the steam three times over. Of course the present single section at Shirleywich could not do that. He should think that the apparatus would meet all the requirements with regard to the salt supply of India, where the greater density and smaller grain of the salt would be an advantage rather than otherwise.

Mr. Fryer wished to know what became of the salts of lime and magnesia which remained in the mother liquid after the deposition of the crystals.

Mr. Schönheyder said that he thought the salt industry was very much to be congratulated upon the step which had been taken in trying a rational way of producing salt, instead of the present old-fashioned and wasteful method. Endeavours had been made for many years to get the salt-makers to produce salt in the cheapest manner, but their cry had always been that they got very little for their salt, and either they were too busy to do anything, or else were slack and too poor to afford alterations. But he must say at the outset that Mr. Nursey had gone rather too far in claiming novelty for the apparatus. He (Mr. Schönheyder) saw very little novelty in it. The manufacturing of salt in a manner similar to the obtaining of fresh water by distilling salt water, or of concentrating sugar syrups, by the multiple effect system, had

been practised on the Continent for a great many years. As long ago as 1876, M. Piccard, of Paris, took out a patent for an apparatus almost identical with that which had now been described. The only difference was, that instead of a collecting chamber at the bottom D, he had two sluice valves, and of course a space between the two. The mode of working was to open first one sluice valve, and allow the salt which had separated from the brine to fall into the space between the valves and after an interval of time, the length of which was ascertained by experience, the upper valve was closed and the lower valve was opened. [The speaker illustrated his meaning by a sketch on the blackboard.] From the lower valve the salt fell into a small truck which was, together with a tube attached to the valve, immersed in an open vessel. As soon as the salt had fallen into the truck, the valve was closed and the truck was drawn out to the top above the level of the brine, and the salt was removed from it in a convenient manner of which it was not necessary to enter into detail. It seemed to him that beyond a difference in the mode of extracting the salt there was very little difference between the apparatus of Dr. Pick and the apparatus of M. Piccard. It seemed to be a disadvantage in Pick's apparatus that when the bottom door was open to withdraw the salt, the bottom chamber D naturally became filled with air, which would have to be abstracted. The whole of this chamber had to be exhausted of air every time the salt was withdrawn and that threw an additional amount of work on to the air-pump, so that the latter must be made larger in order to do the ordinary work which it was required to do plus the exhausting of the chamber D. It would be noticed that in the apparatus of M. Piccard the air was never allowed to enter the pipe through which the salt was discharged. That pipe was always full of brine. The salt descended through the brine into the truck below, and the truck was hauled out without the air entering the apparatus. Of course the salt had to be put upon some kind of draining apparatus, but the bottom of the truck might be used for that purpose. He wished to ask Mr. Nursey what difference there was in the quality of the salt obtained from the three pans. He presumed that by varying the temperatures of the three sections considerably, he could produce very different qualities of salt. He had also intended to ask the question which had already been put, how the impurities, which were in the natural salt bed and in the brine, were separated. He noticed that a pipe and trap were shown for taking away the water of condensation from one of the drums. He presumed that there was

the same system for the other drums. A large amount of heat would be lost in that way, and in addition to that, traps were as a rule very troublesome to work; in fact, he did not know whether there was any really good trap in the market.

Mr. NURSEY said that a pump was provided.

Mr. SCHÖNHEYDER said that if there was no connection for removing the air from the chamber D, the air must necessarily pass up into the pans of the apparatus, and require to be removed in some other manner, or must vitiate the vacuum. In the first section there was a pipe clearly shown as leading from the drum to the trap. There was a much better arrangement now extant for taking away the water of condensation, and that was by continuing the drain pipe down to a certain depth making it into a syphon, and allowing the water to pass into the next drum. By that means the whole of the water of condensation was removed from the drum without the loss of any steam, and the excess of heat which was in the water of condensation in one drum went into the next. He believed that he was right in saying that there was shown a pipe for the purpose of removing the air from the chamber B.

Mr. NURSEY remarked, that was so, and that it was in connection with the condenser.

Mr. SCHÖNHEYDER said that he thought that it was well known by this time that air was heavier than the vapour of water at the same pressure and temperature. Therefore all pipes of that kind should pass away from the bottom of the chamber, and not from the upper part. If they were taken away from the upper part only a portion of the air was removed.

Mr. DRUITT HALPIN, referring to the size of the crystals, said that he supposed that in the manufacture of salt the same principle applied as in the manufacture of sugar. It was to a great extent a question of the speed of evaporation. The more slowly the formation of the crystals took place the larger the crystals would become, and the more speedily the water was driven out the smaller the salt would be. Some years ago, Mr. Alliott, of Nottingham, and he, arranged an apparatus to apply that principle in sugar making. The crystals were to a certain extent formed after the sugar was boiled and while it was being cooled, and they put jackets round the coolers so that if they wanted to get the crystals formed quickly water was run through the jacket. In this way small crystals were obtained. If, on the other hand, time could be afforded, steam was run through the jacket, and very large crystals were the result as the cooling took place very slowly.

Mr. A. FLETCHER said that he had had the advantage of

seeing the single apparatus at work at Shirleywich. As it was only a single apparatus they could not obtain the economy which was expected to result from the triple effect apparatus. In his mind the chief difference between the old and the new systems was that the evaporating surface was vertical in the new system, and horizontal in the old. In the case of the horizontal surface the salt formed was deposited on it, and there was nothing to prevent the fire underneath having a destructive action upon the pan. Where the vertical surface was used, and rapid ebullition was kept up, the salt could not settle on the heating surface. That was just the point at which the two forms of apparatus differed in principle. The other differences were matters of detail, though of course many of these were important. By means of the triple effect there was a saving of a vast quantity of heat. Anyone who visited the salt pans under the old system must be aware of the enormous waste of heat. There was such a cloud of steam that the pan could not be seen at the distance of a yard. The men had to work half naked, and the whole process went on in a slovenly way. It might be hoped that under the system now proposed the emission of black smoke would be prevented. There was great difficulty in effecting this under the old system, as the heat of the fires under the salt pans could not be maintained sufficiently high to render the combustion of the gases complete without great danger to the pan. Under the method now proposed, however, the fires would be applied to ordinary steam boilers, and complete smokelessness might be expected. He thought that they would all congratulate the inventor if the new system were eventually carried out.

Mr. A. H. Whipham, having seen the apparatus at Shirleywich, said that it appeared to be a great deal more scientific than the old-fashioned pan. He wished to know whether the new apparatus could make all kinds of salt. There was a great demand in the neighbourhood of Middlesborough for fishery salt, and if such could not be produced, of course that would be very much against the apparatus.

Mr. Howson, supplementing his previous remarks, said that he had forgotten to mention the subject of density. Great density was an advantage when salt had to be stowed on board ship, but, as far as he was aware, it was a disadvantage in other respects.

Mr. R. Crosthwaite said that a remark had just been made about the air rushing back, but this was prevented by the valve. He had seen the apparatus at work, and had observed that the tube which came in, admitted air to the lower chamber,

so that the water was drawn up from the salt, and the salt was almost dry.

Mr. A. H. COOPER said that he had come as a visitor to hear the particulars of this wonderful invention. It must prove of general interest to learn that there was a probability of doing away with the injurious conditions to which the workmen, while making salt, were at present subjected, as by evaporating the brine in a vacuum, the production of the noxious gases would be avoided. He should much like to see the apparatus working.

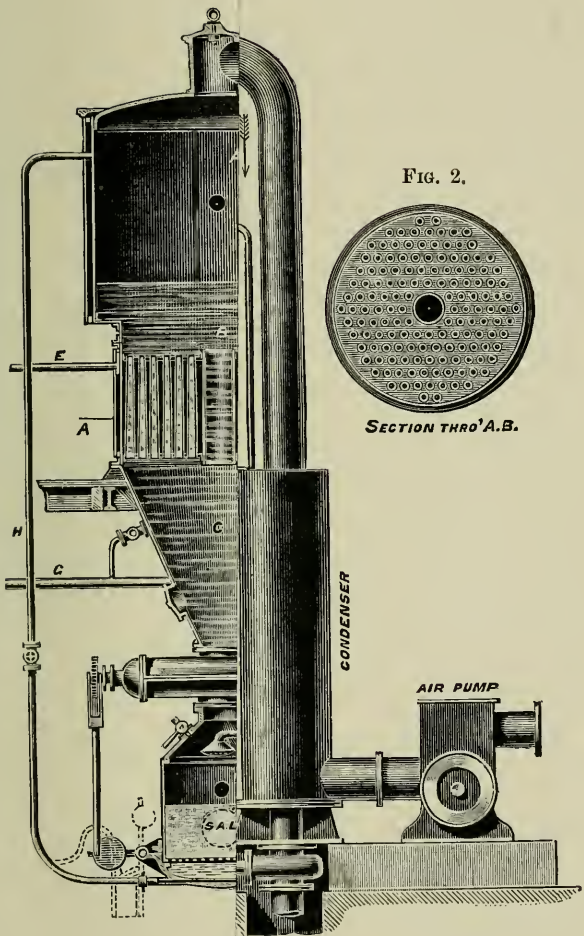
Mr. MORISON said that some of the questions which he should have liked to ask Mr. Nursey had been anticipated by previous speakers. But he should be glad to be informed as to what time the salt required for deposit, and whether there was any certain means of ascertaining that time. He supposed that different brines had different densities, and that therefore they required different times for evaporation. The vertical position was chosen for the tubes with the object of keeping them clean, but it was to a certain extent a disadvantage to give a vertical hea ting surface in contradistinction to a horizontal one, which, he apprehended, was far more valuable in all evaporating vessels. Of course for sugar pans the arrangement was slightly different, as the condensed liquor was drawn off from the first pan to the second, and so on, in the triple effect, and was not drawn away from the first pan. The worms were nearly always made horizontal, though there were some vertical worms in use.

Mr. NURSEY, in reply, said that Mr. Rigg and other speakers had referred to the question of different degrees of fineness in the salt produced. Their remarks had been mainly answered by Mr. Halpin. The degree of fineness resolved itself into a question of the rate at which the machine was driven. If it was driven quickly it would produce fine salt, and if it was driven slowly, it would produce a coarser salt. He was informed that they could produce salt of any required degree of fineness, by means of the apparatus, but the fact was not within his own experience. He wished it to be clearly understood, before he went further, that he was only responsible for one single section of the apparatus, worked in the way which he had explained. Mr. Fryer had asked what became of the salts of lime which were in the brine. The answer was that where such salts occurred, and it was necessary to remove them, the product was washed, and the extraneous matter was got rid of in that way. The salt which he had seen made in the machine was very pure. Mr. Schönheyder had spoken very forcibly on

the subject, and had told them very properly that there were other apparatus for the production of salt, and he had sketched on the board the apparatus of M. Piccard. But he (Mr. Nursey) could not see the slightest resemblance between M. Piccard's system, and that of Dr. Pick, except that there was an arrangement in each for letting the salt down from one part to another But that feature was common to other systems which had been tried. As far as his information went, most apparatus, which had hitherto been tried, had proved a failure, owing to the difficulty and the expense attached to the effecting that which Dr. Pick had done, viz. to draw off the brine immediately it came down with the salt, clean away to the upper portion again. And therein lay the success of the vacuum filter system as applied to salt making. Mr. Schönheyder had also referred to the filter being exhausted of air. That might or might not be necessary in the triple apparatus. In the practice with the single section at Shirleywich, the salt was simply let down, and the brine exhausted back to the boiling chamber. The filter chamber was then opened, the salt taken out, and the filter closed again. There was no trouble or difficulty with it in any way. With regard to a small quantity of air getting back again, there was no appreciable effect produced by it in the working. Mr. Schönheyder had referred to the difference in the size of the salt crystals in the three different sections. There would probably be a difference, but uniformity might possibly be secured by driving the three sections at the same rate. But the result of the apparatus had been really tried. The apparatus which he had described was largely used in other industries minus Dr. Pick's vacuum filter, which latter gave the apparatus the finishing touch for salt making. Mr. Whipham's remarks as to the fineness of the salt were answered by the statement that the apparatus could be made to produce crystals of different sizes. Mr. Howson stated that the great density of Pick's salt was a disadvantage. No doubt he had a sound reason for making that statement, for he came from the salt-producing district of Middlesborough. At the same time, he (Mr. Nursey) conceived that for the purpose of transport, density would be a very great advantage. The saving of space in stowage was very much to the credit of the density. Mr. Cooper, and, he believed, Mr. Hoalsson wo, expressed a wish to see the apparatus. He (Mr. Nursey) would have pleasure in enabling them to do so. As to the time required for the deposition of the salt, to which Mr. Morison had referred, the charge of salt was drawn at Shirleywich about every hour, and about a hundredweight was taken away each

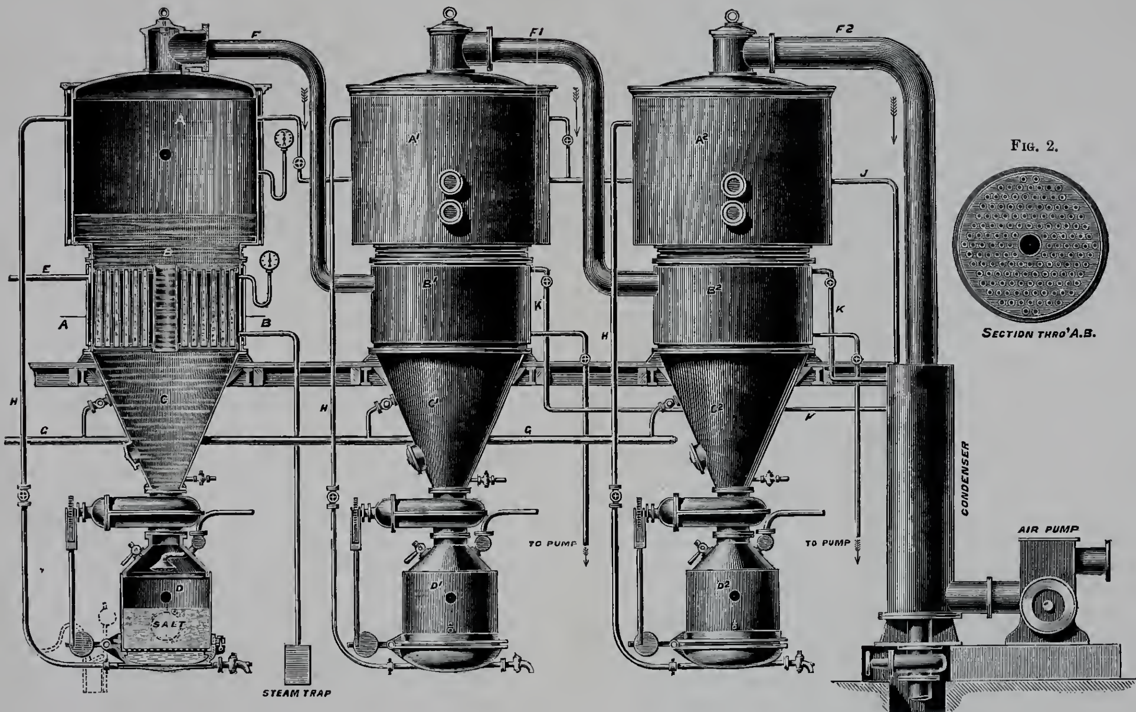
time. With regard to the triple apparatus, it should be borne in mind that it had not yet been applied in practice to the manufacture of salt, but the design which was represented in the diagram had been carefully worked out by Dr. Pick, and it was that with which he (Dr. Pick) proposed to carry out his principle into practice.

Fig. 2.



[*To face p.* 132.

Fig. 1.



[*To face p.* 132.

VACATION VISITS.

During the summer and autumn of 1890, the following visits were made :—

On the 17th June the Thames Iron Works and Shipbuilding Company's Works at Orchard Yard, Blackwall, were visited by the members, who were most courteously received by Mr. A. F. Hills, managing director, and the late Mr. W. Hayward, the manager, and conducted over the works, in two parties, by those gentlemen. The works, which cover nearly 30 acres of ground, are situate in the parish of West Ham, and include the largest shipbuilding yard on the Thames, the number of men employed being over 3000. For thirty years the company has been principally engaged upon the building of warships, including such notable vessels as the *Minotaur*, *Serapis*, *Earl de Grey and Ripon*, *Volage*, *Active*, *Magdala*, *Cyclops*, *Rover*, *Superb*, *Swift*, and *Lennox*, besides many of the best ships in the fleets of foreign powers. Among the contracts in hand at the present moment special mention should be made of the fast cruisers in course of construction for the British Admiralty. The *Blenheim* (sister-ship to the *Blake*, now building at Chatham dockyard) is one of the new fast cruisers for the British Navy. Her displacement is 9000 tons, and her principal dimensions are :— Length, 375 feet; breadth, 65 feet; depth, 38 feet. She was commenced in September 1888, and will probably be launched in the early part of next month. She will be fitted with triple expansion engines. The engines are to have a collective power of 13,000 H.P., for twelve hours steaming at natural draught, and 20,000 H.P. for four hours with forced draught—the corresponding speeds under these conditions being 20 knots and 22 knots per hour respectively, with twin screws, by Messrs.

Humphreys, Tennant & Co., and will be one of the fastest and most powerful cruisers of the Navy. It is expected that the *Blenheim* will be ready for service in about a year's time, and she will, when fully equipped, carry an armament comprising two 9·2-inch 24 ton guns and ten 6-inch breech-loading guns, sixteen 3-pounder quick-firing guns, one 1-inch and seven 0·45-inch Nordenfelt guns, and four 14-inch Whitehead torpedo tubes. On an adjacent slip (from which the *Warrior*, the first ironclad ever built for the British Admiralty, was successfully launched twenty-five years ago) the *Grafton*, a cruiser of 7500 tons, has been in progress for some seven or eight months, and in her present condition afforded the visitors an excellent opportunity of observing the construction of her double bottom and her protected deck. Her length is 360 feet, and her breadth 60 feet. She will be fitted with engines of 12,000 indicated horse-power, also by Messrs. Humphreys, Tennant & Co., which will propel her at a speed, under forced draught, of 19¾ knots. The *Theseus*, sister-ship to the *Grafton*, will be laid down on the slip now occupied by the *Blenheim* as soon as the latter is launched. Her engines will be supplied by Messrs. Maudslay, Sons & Field. In addition to the work in hand for the Admiralty, the company is building several passenger boats for service in England and abroad. A considerable portion of the extensive workshops of the company is engaged in the construction of bridge, roofing, and girder work, buoys, tanks, &c., for which the company has numerous orders in hand. The two large dry docks facing the river Thames, together with the accommodation afforded by its extensive forge, rolling mills, iron and brass foundries, engine and boiler shops, place the company in a favourable position to undertake not only shipbuilding contracts, but to carry out the heaviest description of shipbuilding and engineering repairs. Every facility was given to the visitors to closely inspect the operations carried on at the works, the *Blenheim* being the central point of interest. Before leaving, a vote of thanks was accorded to the Company, through Mr. Henry Adams, the President. Mr. Hills, in responding, pointed out the fact that the Thames, for some years a neglected shipbuilding river, was once more able to

show that it still held the proud position of turning out only the best class of work, a sentiment which close observation enabled the members to heartily endorse.

On the 18th July the members were conveyed to Woolwich by the steamboat *Kaiser*, especially chartered for the purpose, and an interesting visit was made to the Royal Arsenal, where the members were kindly permitted to land at the T pier, and were courteously received by the officials.

The most noticeable operations carried on at the Arsenal are the "squirting" of rod-lead, as a preliminary operation in the manufacture of small-arm bullets; the rod of lead, after leaving the squirting machine, which is actuated by hydraulic pressure, is cut into the requisite lengths, squeezed into shape, and finished in accordance with a standard. The other processes carried on included the manufacture of cartridge cases, moulding and casting of projectiles in the Laboratory Department; dove-tailing and tenoning, wheel-making, stamped forging by hammer and hydraulic press, and the general engineering work including turning, planing, and slotting in the Carriage Department. In the Gun Factory are carried out the processes of casting steel ingots, forging parts of heavy guns by the 40-ton steam hammer, turning, boring, and rifling guns of various sizes, trepanning ingots and forgings, tempering steel tubes and shrinking hoops on guns. Two forms of crusher gauges were seen—one adapted to be screwed into a tapped hole in the breech end of the gun, and the other to be put in loose behind the powder. The crusher gauge consists of a thick steel case of cylindrical form, containing a cylindrical cavity. One end can be unscrewed and taken off. Through this end a steel plunger, about half inch in diameter, is fitted very accurately. A cylinder of annealed copper is placed in the cavity, and the end of the plunger rests against it. At the time of the explosion of the charge in the gun the pressure of the gas forces the plunger in and "upsets" the copper cylinder, and the reduction in its length as measured by a micrometer gauge gives a fairly accurate indication of the pressure attained. Several 45-ton guns in various stages towards completion were viewed, also

tubes and "jackets" for other sizes. To shrink on the successive tubes, the partly finished gun is lowered muzzle downwards into a pit, a number of which are arranged for the purpose around the 200-ton crane, the gun is then blocked up vertically, and the heated tube lowered on by means of the crane.

In the wood working department interest was evinced in the operation of sawing out irregularly curved and twisted pieces of ash for saddle blocks. This is done by means of a band saw having a rocking table. The axis on which the table rocks passes through the saw edgeways. The operator keeps the lower side of the block from which the pieces are to be sawn flat upon the table, and times his rate of following up the cut with the movement of the table—a part of the framework of the sawbench which the edge of the table passes and the block being marked at intervals for this purpose. Another process of interest in this department is the making of carriage wheels. The tyre sections are sawn out with a band saw in the ordinary way. The spokes are turned to almost their finished form, tenon included. A revolving cutter is employed, which is attached to a sliding carriage. This carries a small wheel which is kept up to an iron "dummy" spoke, and which revolves in unison with the spoke in course of being cut out. Two spokes are fitted into each tyre section, which, having been trimmed to the proper angle at the ends, and the pins fitted in, are brought to a machine for putting together. This consists of a number of small hydraulic cylinders with their plungers directed radially inwards. The number of cylinders corresponds with the number of sections in the wheel, and each plunger carries on its end a sector-shaped shoe, which rests against the wheel section. The sections of the wheel are arranged in position. The pressure is then put on gently, and when the wheel is nearly closed up, the ends of the spokes, which abut against each other in the centre, are clamped between two discs so as to keep them all level. More pressure is then put on until the ends of the sections and the ends of the spokes in the centre are pressed into intimate contact. After this the tyre is shrunk on and the wheel mounted in a lathe and the centre and tyre trued up.

The chamfering of the edges of the tyre between the spokes

is performed by two revolving cutters, which are mounted on frames, so that they may be pushed away out of cut by the spokes as they pass, suitable projections being attached to the frames to catch against the spokes as the wheel revolves.

The third and last visit of the season was made on the 16th September to the London and North Western Railway Works at Crewe.

These works are of a very extensive character and occupy an area of over 85 acres. The members upon their arrival were first shown over the Bessemer Steel Converting House, where the process of steel making is carried out, after which they proceeded past the Siemens-Martin furnaces to the 14-inch merchant mill, where the spring plates and fish plates are rolled. Here the latter, after being passed through the rolls, are sawn to the required lengths, punched, straightened, and finished ready for sending away. Thence the members were taken to the rail mill, which was occupied in rolling 30 feet lengths of rails weighing 90 lbs. per yard, and to the points and crossings shop, where the different kinds of switches and crossings were in process of manufacture. A visit was then made to the boiler shop, where locomotive and stationary boilers, as well as bridge work, were seen in different stages of manufacture, the hydraulic riveting machinery being especially worthy of notice. Having viewed the flanging shop where the various plates used in the boilers are stamped and flanged under powerful hydraulic presses, and the boiler mounting shop, where the boilers are tubed, mounted with their various fittings, and tested, the iron foundry was visited, where the different machines for plate moulding could be seen in operation. The tender shop, where, in addition to the tenders and tanks for the locomotives, the steel frames for the 42 feet carriages with the radial axle having been inspected, the next place of interest was the forge, where was seen the large plate mill, used for rolling boiler and frame plates. Other objects of interest in this department were a large circular saw for cutting up bars and slabs cold, a Ramsbottom 30 tons duplex steam hammer, and the tyre rolling and finishing mill. The iron forge where the merchant bars are

rolled was next visited, after which the members proceeded through the steel foundry to the paint shop, where the various processes in connection with painting the engines were seen. Here the party re-entered the special saloon carriages and was conveyed to the "deviation" shops, where the chain and other testing machines in the testing department were seen at work. After passing through the millwright's shop to the joiner's shop, where a number of wood-working machines were seen in operation, the iron and stamping forge was reached, where the various articles there manufactured were exhibited. The next shops visited were the erecting shops, where the building of new locomotives was in progress, as well as repairs to engines which have been running. In the wheel shop were to be seen a number of cast steel wheels and compound engine cranks and straight axles in various stages of completion; also the machine for cutting out the throws of the crank. The last to be visited was the fitting shop, where the various parts of the engines are fitted together and finished before being sent to the different erecting shops. Here were to be seen a number of tools which have been especially designed for turning out the work quickly and economically. The tour of the works having now been completed, the members rejoined their saloon carriages and were conveyed back to London by express train.

October 6th, 1890.

W. NEWBY COLAM, Vice-President, in the Chair.

SEWER VENTILATION.

By W. Santo Crimp, Assoc. M. Inst. C.E., F.G.S.

There is probably no subject in connection with sanitary science regarding which more has been written, but fewer experiments made, than the ventilation of sewers. The question is undoubtedly one of extreme difficulty, as the conditions vary in almost every sewer, and one would, therefore, have thought that writers would have at least made an attempt to ascertain the actual conditions prevailing in each particular instance, before proposing methods that would in all likelihood fail, in consequence of there being no reliable data upon which to work. In nearly every paper on the subject examined by the author, the writer has assumed that temperature is practically the only agent causing movements of sewer-air, an assumption greatly wanting in basis, as we shall see later on.

The composition of sewer-air is now well known, thanks to the precise investigations of Miller, Beetz, Miquel, Carnelly, and Haldane.* The experiments of the two last-named observers are of especial interest, since they were made with a view to ascertaining the number of micro-organisms present in sewer-air, as well as the nature of its chemical constituents. The average results obtained at Dundee and at Westminster† are given in the subjoined table:—

April 19 to May 19, 1886.	Temperature Fahr.	Vols. Carbonic Acid, per 10,000.	Oxygen required to Oxidise the Organic Matter in 1,000,000.	Number of Micro-organisms per litre.	In Excess of Atmosphere. Temperature Fahr.	Carbonic Acid in 10,000.	Oxygen to Oxidise Organic Matter.	Number of Micro-organisms per litre.
Sewer-air	54°	7·5	7·2	8·9	5·2°	3·8	4·9	7·0
Atmosphere	49	3·7	2·2	15·9	..	..	..	..

* See 'Proceedings of the Royal Society,' vol. xlii.
† 'Transactions, Sanitary Institute,' vol. ix.

The results are compared with the air obtained in schools and some dwelling houses, and as regards micro-organisms, the sewer-air contained fewer, but it may well be remarked that these organisms may be, and probably are, of a widely different character.

With regard to the carbonic acid found in sewers, it is known that that gas is freely disengaged during fermentation, and its presence may be partly accounted for by that process, and partly by the passage into the sewers of the ground-air, which contains an excess of carbonic acid over that of the atmosphere. Sewers are rarely water-tight, much less air-tight, and when they are constructed in porous soils, and are not well constructed, there is no doubt a frequent interchange or mingling of ground-air and sewer-air.

In cesspools, and in sewers of deposit,—and possibly in well constructed sewers, but in less degree,—hydrogen sulphide, ammonium sulphide, carbon dioxide, and other gases are found, and have been known to produce various symptoms of poisoning, and even to cause death.* It will be conceded, however, that these gases are in themselves incapable of producing such specific disease as typhoid and other zymotic fevers, and we look for the explanation of the undoubted occasional causation of those diseases by sewer-air, to the fact that the germs of those diseases must sometimes be there present. Messrs. Carnelly and Haldane found large numbers of organisms in sewers, where a junction or branch sewer caused much splashing by the falling of its contents into the main. This is an important fact in its bearing on sewer ventilation, as in the absence of air currents, these germs would undoubtedly fall back into the liquid and be carried to the sewage outfall works. Rapid air currents on the other hand, would tend to carry numbers of them into the atmosphere, or possibly into the rooms of badly drained houses.

We may now briefly consider the necessity for ventilating sewers, and, secondly the amount of ventilation to be provided. Dividing sewers into two classes, viz. large ones in which men are frequently employed, and small ones into which they cannot enter, we may consider the case of the larger ones first.

Whether sewers be well constructed or not, gases due to fermentation and putrefaction must necessarily be present because that portion of the sides which is alternately wet and dry becomes more or less coated with small particles of fæcal matter, grease, and other of the solid constituents of sewage, although in well ventilated sewers the gases are often too diluted to be offensive. Having regard to the health of the men employed

* 'Practical Hygiene.' Parkes, 1883.

in flushing, cleansing, repairing, &c., fresh air should be abundantly provided in those sewers in which they are at work, and in these cases, therefore, ventilation should be carried to the fullest practicable extent. Unless, however, it can be proved that disease germs are quickly destroyed by contact with fresh air, the effect of such ventilation would be merely to dilute offensive and when concentrated, deadly gases.

Next with regard to small sewers, it may with reason be asked, why should they be ventilated at all? There can be but one reason, and that is, to prevent sewer-air from finding its way into badly drained houses; for it must be admitted that a well-drained house is impervious to sewer-air, any that may be forced through the disconnecting trap between the drains and the main sewer passing harmlessly up the ventilating pipes of the house. Is there then any reason why small sewers should be ventilated in the ordinary sense of the term, that is by means of frequent openings at the street level? Suppose there are substituted small pipes carried up houses, trees, &c., in place of the offensive street ventilators, what happens? The sewer-air may perhaps be less diluted than before, but the importance in the difference of method is that in consequence of the feeble air currents which would generally prevail in the sewers, the disease germs thrown into the sewer-air would for the most part fall back into the sewage, and not be swept out at the ventilators as in the case of fully ventilated sewers; moreover, there might easily be provided sufficient vent for the escape of the sewer-air during heavy rains, so as to preclude the possibility of its being forced into badly drained houses.

If an estimate be made of the volume of air that would be discharged by a 6-inch pipe, 50 feet in length, under a water pressure of 2 inches, the usual seal of a trap, using the formula

$$v = 396 \sqrt{\frac{h\,d}{l}}$$

where v = velocity, in feet per second.
h = head, in inches of water.
d = diameter, in feet.
l = length, in feet.

we find that it would amount to 660 cubic feet per minute, or we might say that the aerial contents of a 12-inch sewer, about 300 yards in length, would be discharged in one minute, allowing for a small stream of sewage that may be flowing along the invert, as in the case of most branch sewers. It may be seen, therefore, that the number of vents to be provided need not be large; probably one or two for each branch sewer would be sufficient.

The cause of the movements of sewer air may next be considered, and here the author would remark that in his opinion the experiments made by him upon the Wimbledon sewers—an account of which has already appeared in the 'Proceedings of the Institution of Civil Engineers,' *—prove conclusively that the only agent producing movements of sewer air that can be measured by an anemometer, is the wind. To those who have been accustomed to regard temperature as the agent causing movements of sewer air, the statement may appear to be a startling one. It is true that in the paper on the Ventilation of Sewers, by Mr. Baldwin Latham, read before this Society on April 3rd, 1871, a brief allusion is made to the effect of the wind on sewers. Mr. Latham says:—"Wind blowing over the surface of ventilators in a street has a material effect in changing the currents of air within the sewers." But whilst the effect of the wind is discussed in a few lines, there is upwards of a page devoted to an exposition of the laws of gravitation, and the effect of differences of temperature between sewer air and the atmosphere, which differences are assumed to produce very rapid movements, the calculations being based on the fundamental formula relating to falling bodies.

It could be demonstrated theoretically that in a chimney of a certain size and height, and up which a defined number of heat units passed per minute, there would be a velocity of so many feet per minute; but a puff of wind, deflected perhaps by a neighbouring building, may upset the calculation by reversing the current and filling the room with smoke. So with sewers, the differences in temperature are slight indeed compared with the case just considered; but on the other hand, from the customary position of the street ventilators, the sewers are much more subject to the action of the wind, or rather, the wind is more capricious in its action upon them, owing to its direction being constantly changed in passing over a town.

With regard to the experiments made by the author at Wimbledon, he was induced to undertake them because of the results attending the trapping off the main of some branch sewers, which passed up hills somewhat steep. Traps were inserted in each branch at its junction with the main sewer, and an air shaft, brought to the surface, was provided on the upper end of each trap. When the work was carried out, the author was under the impression that air would pass into the branch sewers by means of the air shafts, and would pass up the hills to the exits carried above the roofs of buildings near the

* See Min. Proc. Inst. C.E., vol. xcvii. 1889.

uphill ends of the sewers. It was soon found however, that the sewer air frequently poured out of the air shafts at the bottoms of the hills, showing that down-hill currents were often prevalent.

The author then determined to ascertain the conditions under which the up and down currents were produced, and experiments which he carried out continuously for one year were commenced on January 11th, 1888. A number of disconnected experiments were made during the last six months of 1887, but they were of little value, beyond proving the existence of frequent down hill currents in the sewers.

The subjoined account of the experiments has been abstracted from the paper by the author, already referred to * :—

"The first experiment was made on the 1st of July, 1887, when an anemometer was placed in an air shaft, at 12.30 p.m., and at 7 p.m. had recorded an average downhill velocity of 104 feet per minute; at 9 a.m. on the 2nd, the average velocity also downhill, due to the fourteen hours, amounted to 42 feet per minute. The air-shaft is 6 inches in diameter.

"About the date mentioned an experiment was made at Wimbledon by Mr. Fewson and the author, in which an 'electrolyser,' in conjunction with a 'Capell' fan was employed. The capacity of the fan was 18,000 cubic feet per hour; the length of 12-inch sewer operated upon was 620 yards; the street gullies were connected with a separate drain; many houses draining into the sewer were provided with traps, others were not, whilst it is probable that in some cases in those of the older houses, the drains acted as sewer ventilators; the conditions were, in short, such as are generally prevalent, except in new streets where the houses are drained in accordance with the model bye-laws. The fan was connected with the sewer at its uphill termination. All the manholes and ventilators on the sewer to be experimented upon were closed, with the exception of that at the foot of the hill, which was one of the air-shafts already referred to.

"The air was found to be passing steadily down the sewer, and on setting the fan to work as an extractor, no effect was observable at the foot of the hill, showing that the fan procured its supply of air from the sewer at a point or points remote from the air shaft, and that for the time being, air was passing out at both extremities of the sewer, and into it at some intermediate points; that, however, at the top of the hill being withdrawn by artificial means. Had the sewer been airtight, and all connections trapped, the fan would have changed the ærial contents of the sewer in five minutes.

* Min. Proc. Inst. C.E., vol. xcvii. 1889.

"An anemometer was next placed in the air-shaft of the sewer of an adjoining hill, when an experiment, extending over twenty-four hours, gave a downhill velocity of 52 feet per minute, the air-shaft being 6 inches in diameter. The fact that sewer air passes up sewers is well established, and in order to ascertain the conditions under which both the upward and the downward movements were effected, a small brick chamber was constructed adjacent to the air-shaft of the sewer, experimented upon by Fewson's apparatus; a central division was built, provided with two openings; each opening was furnished with a mica valve, but on opposite sides of the wall (Fig. 1).

"An anemometer was placed in each opening, and all the sewer air passed through one, whilst all the fresh air entering the sewer passed through the other. Two self-registering maximum and minimum thermometers were employed in the sewer, one for ascertaining the temperature of the sewage, the other that of the sewer air. This latter was suspended in the sewer at a point distant about 250 yards from its downhill termination. A plan and section of the sewer experimented upon are given in Fig. 2.

"At the end of the sewer a 6-inch ventilating pipe is carried above the roof of a house, but the end of the pipe is not provided with a cowl. The ventilating grate openings on the air-shaft at the syphon trap are of an area of 28 square inches. During the period of twelve months, whilst the experiments were being made, the street ventilators were closed with the exception of the air-shaft over the syphon trap. The depth of the sewage is rarely greater than 2 inches, the gradient being sharp. The general results are shown in the subjoined Table and Diagram.

SEWER AIR EXPERIMENTS, WIMBLEDON, 1888.

Month.	Temperature—Air.	Temperature—Sewer Air.	Difference.	Temperature—Sewage.	Number of Days. Up.	Down.	Both.
	°	°	°	°			
January ..	35·75	42·70	+ 6·95	46·30	13	12	8
February ..	34·75	42·30	+ 7·55	44·75	19	29	19
March ..	38·50	42·10	+ 3·60	45·41	13	27	11
April	43·50	44·50	+ 1·00	47·60	19	30	19
May	52·00	49·20	− 2·80	50·10	11	26	11
June	57·70	54·25	− 3·45	53·90	3	27	3
July	58·00	56·65	− 1·35	54·80	2	28	2
August ..	59·10	57·75	− 1·35	55·65	4	27	4
September ..	55·80	57·70	+ 1·90	56·70	5	20	5
October ..	44·70	53·10	+ 8·40	51·25	3	12	1
November ..	46·40	50·65	+ 4·25	48·30	5	26	5
December ..	41·00	48·85	+ 7·85	40·60	—	9	—
	47·26	49·98	—	49·61	97	273	88
	Means.				Totals.		

First may be considered the effect, if any, of temperature. The table shows that during eight months of the twelve, the average temperature of the sewer-air was higher than that of the atmosphere, whilst during the remaining four months, the opposite conditions prevailed. We should expect therefore, that, speaking generally, the effect of temperature would be to cause up-currents in autumn, winter, and spring, and down-currents in summer, but what evidence is there that such a state of affairs actually existed? None whatever; on the contrary, during the coldest month of all, February, there were down-currents on every day, whilst up-currents were registered on nineteen days only. It should, however, be pointed out that the currents were often too feeble to work the anemometers, but the positive results are such as to prove beyond doubt that there is a much more powerful agent than temperature in causing movements of sewer-air.

We cannot find any evidence that the flow of the sewage exerts any appreciable effect; the author is of opinion that such a source of power, as affecting movements of sewer-air, may be entirely disregarded.

Before passing on to an examination of the effects of the wind, we may briefly consider some points in connection with temperature. It is rather striking that the temperature of the sewer-air was lowest in March, and had it not been for the quantities of snow that fell in February, which, on melting, found its way to the sewers, the sewage would also have been coldest in that month. But the temperature of the air was 4° higher in March than in February, and we must look to the fact that the temperature of the earth at the depth at which the sewer is laid—10 feet—exercises a considerable amount of influence upon the sewage and the sewage-air. We know that the temperature of the earth at a depth of 10 feet is not constant throughout the year, but that there is a variation of several degrees. The summer heat is conducted slowly downwards, and the maximum temperature at a depth of 10 feet is reached about one month later than is the maximum quite near the surface, and the same rule holds good with regard to the minimum temperature.

Now, a system of sewers consists principally of branches, containing but small volumes of sewage. The sewer must necessarily acquire the temperature of the ground with which it is surrounded, and it causes the sewage to quickly attain the same temperature. That at any rate is the conclusion arrived at by the author after a careful consideration of the data obtained by him.

Incidentally, it would appear to be advantageous to construct

sewers at such a depth as to take the fullest advantage of the earth temperature. The sewage might then be cooled in summer, thus keeping down putrefaction, and in winter it might be maintained at a temperature advantageous to its application to land.

With regard to the principal agent causing movements of sewer-air, the author would remark that at first, being imbued with the idea that it was temperature, the results were very puzzling. For the first week indeed, after commencing the experiments, the data appeared to possess no value. Then a gale from the north-east and east occurred, and the movements of the sewer-air were extremely rapid and uphill in direction. A week later a westerly gale was experienced, and the movements were as rapid as before, but down-hill in direction. These two gales gave the author the clue, and not long afterwards it was easy enough to predict the direction of sewer-air currents in the experimental sewer by merely observing the direction of the wind.

Subjoined are some of the more noticeable features in connection with the year's experiments :—

In January the movements were very slight until the 16th, 17th, and 18th, when fresh N.E. and E. breezes prevailed. On those three days, of the total volume recorded as passing up-hill during the month, one half was measured. On the 24th, 25th, and 26th, strong westerly winds prevailed, and on those three days, of the total volume recorded during the month as passing down-hill, three-fourths were measured. During the early part of February, light N.W. to W. winds produced down-hill currents, whilst the strong N. and N.E. winds during the latter half produced strong up-hill currents, light down-hill currents being also registered every day. In March considerably more than half the quantity registered passed down-hill during the prevalence of strong W. and S.W. winds, on the 8th, 9th, 10th, and 11th; whilst strong N.E. winds on the 18th, 19th, and 20th produced strong upward currents, seven-eighths of the total registered during the month passing up on those three days. In April strong S.W. winds on the 17th and 18th produced rapid down-hill currents, while fresh N.N.E. and N.E. winds on the 25th and 26th were productive of strong up-hill currents. On the 1st, 2nd, and 3rd of May strong S.S.W., S.W., and W. winds prevailed, and rapid down-hill currents were registered, the up-hill currents throughout the month being feeble, except upon one or two occasions when fresh N.E. winds occurred. During June the volume measured as passing down-hill greatly exceeded that passing up even fresh N.N.E. winds being productive of down-hill

currents. It is quite possible that the foliage of trees, which are very abundant on the line of sewer experimented upon, might have deflected the wind, thus producing results the opposite of those before obtained. July was chiefly noticeable for its extreme wetness, and, as regards the sewer-air, for the absence of up-hill currents, N.W. winds on the 10th and 11th producing feeble up-hill movements. The fresh S.W. winds, which frequently prevailed, produced strong down-hill currents. August was free from incident except upon the 1st, when the heaviest rainfall of the year was measured. The wind was N.E., and up-hill currents were not recorded, whilst the down-hill movement was fairly active. The currents generally throughout the month were feeble, but prevailingly down-hill. The same remark applies to September. October was chiefly remarkable for the extreme cold of the first twenty-four days. The mean temperature of the air on the 8th was 36°, whilst that of the sewer-air was 52°·5, yet a difference of 16°·5 failed to produce measurable up-hill currents, the wind being very light from the N.E. Strong S.W. winds towards the end of the month were productive of much down-hill movement. The movements during November were very brisk, fresh winds being prevalent. The usual results were observable, namely strong S. to S.W. winds, causing rapid down-hill currents, whilst fresh E. and S.E. winds produced up-hill currents. Calms and fogs were exceedingly prevalent during December, the absence of wind being accompanied by an almost blank record of movement of sewer-air. Such currents as were recorded were principally down-hill in direction.

During the entire series of experiments the actual volume of air recorded as passing down-hill exceeded that recorded as passing up-hill by very nearly one-third, whilst down-hill currents were recorded on 273 days, as against up-hill currents on 97 days.

The cases given could be multiplied if desirable, but throughout the whole series of experiments the same effects of the wind were observable. The direction of the sewer-air currents was determined by that of the wind, whilst the currents were either strong, or weak, or imperceptible, accordingly as the wind was fresh or light, or calms prevailed.

As the author was desirous to obtain the most conclusive evidence as to the effect of wind, he determined to experiment upon surface-water sewers at a time when they contained no water. The system experimented upon was constructed by the author, and in order to provide for the fullest inspection, he built manholes at the intersection of each junction with the main; these manholes were provided with ordinary ventilating

covers, and similar covers were placed on the inspection shafts at the end of each branch. The system was, in short, fully ventilated.

The movements of the air in these surface-water sewers, in no wise differed from those of the sewers proper, being strong or weak, up-hill or down, accordingly as influenced by the wind. A number of other sewers were tested during the year, but all the evidence was in favour of the wind, and the wind only, as the agent causing movements of sewer-air that could be measured by an anemometer. We may next inquire into the manner in which the wind exerts so powerful an influence.

In passing over the open end of a pipe or shaft in a horizontal direction, it is well known that the wind induces a current out of the shaft subject to its influence ; but in passing over a town, the wind is broken up and deflected in all directions, so that shafts or openings apparently alike may be affected in entirely different manners. The position of some shafts, in relation to surrounding objects, may be such that the air currents may be prevailingly deflected down into such openings, and in these cases, the sewer-air would be driven out elsewhere ; other openings might be affected in the opposite manner. Indeed, in gusty weather the author has found that sewer-air currents are rarely long in the same direction, one minute they may be rapidly up-hill, and the next as rapidly down-hill.

In conclusion may be briefly considered the manner in which the wind may be utilised in the ventilation of sewers. The idea is by no means new; as long ago as 1873, Mr. Ellice-Clarke, then borough engineer of Ramsgate, suggested that the wind should be "injected" into sewers by means of lobster-back cowls, with mouths presented to the wind. Several makers of ventilating appliances have devised more or less ingenious cowls to act either as up-cast or down-cast as may be desired. Mr. Strachan carried out an interesting experiment whilst surveyor to the Chelsea Vestry, a full account of which may be found in the Minutes of the 'Proceedings' of Institution of Civil Engineers, vol. lxxxiv. Mr. Strachan constructed a down-cast shaft in the middle of the sewer, and an up-cast at the end and at the junction with the main, and the results were most satisfactory.

Here, then, is a solution of a most troublesome problem: abolish the insanitary and abominable street ventilators, and carry out a simple but well-devised system of ventilation with outlets high over head, and with simple applications at suitable points for deflecting into the sewers the wind, which is powerful enough to grind our corn, and to carry noble ships from one

continent to another. There may be special cases where some form of cremation of sewer-air may be advisable, and there are some excellent appliances now in the market for the attainment of that object. The author is, however, of opinion that the wind, properly utililized, will generally accomplish all that is necessary in the ventilation of sewers. The author was ably assisted in making the experiments by Mr. G. H. Rogers, Stud. Inst. C.E.

DISCUSSION.

On the motion of the Chairman, a vote of thanks to Mr. Crimp for his paper was unanimously passed.

Mr. G. R. STRACHAN said that he wished to make clear to the meeting exactly what was done at Chelsea in the experiment which Mr. Crimp had referred to; and he would do so by means of a sketch on the blackboard. The sewer was 3 feet 9 inches by 2 feet 6 inches, with 30 or 40 houses draining into it; and there were some gulleys in the streets. The sewer was made in those days when it was considered necessary for men to enter the sewers. The road was practically level, and at one end there was a large and very foul sewer belonging to the Metropolitan Board of Works. The sewer experimented on had a gradient of 1 in 100, and had 4 or 5 ventilators of the ordinary type along its course, and very considerable inconvenience was experienced from it. In consequence of this, the small sewer was practically cut off from the sewer of the Metropolitan Board by a dip trap being built, and a flap valve was put in at the point shown on the blackboard. Every house drain and every connection to the sewer was closed by means of a galvanised flap, so that, substantially, the sewer was a closed vessel. A 15-inch pipe was taken from the sewer up the side of a house, and fitted above the roof with a lobster-back cowl. Whichever way the wind blew, the face of the cowl was always presented towards it. The consequence was that some of the air was entrapped, and forced its way down the shaft into the sewer. It was found necessary simply to provide means for getting the air out. That was done by means of a 12-inch pipe at each end. One pipe was carried up the side of a house, and the other was carried up as a chimney, and had an ordinary chimney pot at the top. He experimented with the sewer for 44 days continuously. He had three anemometers in various positions, and a fourth one used as a check. They agreed with one another within one per cent. Roughly speaking, what occurred during the whole time of the experiment was that

during a heavy gale the sewer was filled and refilled with air perhaps sixty times in the day. On a calm day the number would get down to perhaps thirty; but on the average there was as much air driven down the pipe as would fill and refill the sewer every hour during every one of the days, or even oftener than that. It was very curious to sit inside the sewer, and watch the effect of the wind upon the cowl. In gusty weather the anemometer would spin round very rapidly when the wind was coming down. The cowl was unable to get round as quickly as the wind changed, and the consequence was an enormous out-draught, and the anemometer would spin back again until the air had righted itself. Then it would spin in the other direction. That form of error could not be eliminated, and he was never able to find out that at either of the anemometers at the outlets, there was any evidence of a backdraught. The only difficulty which ever presented itself to his mind about this system of ventilating a sewer was that, assuming that every sewer would fill and refill at the rate of the experimental sewer, foul air, to the extent of 24 times the total capacity of the sewers of London would be distributed into the air; and it was a question whether that would be an advantageous result or not. Upon that point he did not pretend to give an opinion. The effect of the ventilation upon the sewer was very marked. Before the ventilation was carried out the sewer was always wet, and contained that bluish-green slime which always gathered on the tops and sides of sewers; and after the ventilation was started the sewer became dry, and the sides got to their proper colour again. Towards the end, clean water settled on the top of the sewer, but the air was not offensive, though he did not suggest that the sewer would be a pleasant place to spend a holiday in. The system which he had described was one devised by Mr. Harrington of Ryde. The system was a costly one, because way-leaves had to be obtained for carrying the shafts up the houses. The shafts were fixed in such a way that they were not conspicuous upon the face of the wall. He did not hesitate to say that he was one of those persons who, some years ago, realised that the open ventilation of sewers, as practised at the surface of the streets, was not an adequate solution of the question.

Professor Robinson said that he thought that the Society of Engineers were very fortunate in having Mr. Santo Crimp present on this occasion. On the part of the Society, he should like to offer Mr. Crimp their congratulations upon his having assumed the very important position which he now occupied with regard to the County Council of London. It must be a satisfaction to Londoners to know that the question of sewer

ventilation was in the hands of one so competent to deal with it, and one who had given himself so much trouble in solving a very difficult and complicated problem. The paper which had been read was one which deserved very careful study. The facts published in the paper, and also those published in a previous paper which had been read upon the same subject at the Institution of Civil Engineers, pointed conclusively to the necessity of treating the ventilation of sewers in some more systematic manner than had been the case hitherto. He did not go so far as the author, and say that ventilation by the usual grids at the surface of the roads should be abolished, because he did not see how that could be done in practice; but what the author had laid down was, no doubt, quite right. Mr. Santo Crimp had established the fact that the current of air in the sewer was not governed entirely by temperature, as had been generally supposed; but the application of that result in practice was not restricted to any one system of ventilation. The ventilation of a large system of sewers must be dealt with according to the situation of the sewers, and the surroundings. What Mr. Strachan had pointed out, viz., the probable difficulty of obtaining the right of carrying a ventilator in the position which an engineer would think right, would alone be a difficulty of a practical nature which would necessitate various methods of dealing with the ventilation, and so preventing any hard and fast rule being used. As to the effect of a current of air upon temperature, if a ventilator was put at the top of a room with a view to taking off the heated air, in nine cases out of ten the ventilator would do nothing of the sort, but would admit cold air which would follow the law of gravitation, and becoming diffused, would purify the vitiated air. That was a simple illustration which he thought would be to the point.

Sir Robert Rawlinson, K.C.B., said that he should be bitterly sorry if any attempt was made to tamper with the ventilation of the London street sewers as at present existing. He was one of the first inspectors appointed by the 1848 Board of Health, and one of the first towns sewered under that Board was Croydon. The sewers were small earthenware pipes, having bell-mouthed joints, and the works were carried out by one of his colleagues, on the principles then laid down by the head of the department. He (Sir R. Rawlinson) did not, however, pay the slightest attention to those principles when he did not approve of them, for he never permitted the head of the department, who was not an engineer, to interefere with him in anything connected with the engineering work which he had to do. At Croydon small pipe-sewers were used, and it was held that ventilation was not necessary. It was thought

that the current of water within the sewers would take a current of air with it, and discharge it at the outlet. The houses were connected with the sewers by small earthenware pipe drains, which also were unventilated. The result was a fearful outbreak of gastric and enteric fevers. This outbreak occurred to such an extent that Parliament ordered a commission to sit and inquire into the cause. The members of that commission were Dr. Arnot, one of the greatest scientific men England had produced, and Mr. Page, civil engineer, whose work was well known. It did not take those gentlemen long to discover the egregious mistake of attempting to sewer a town without making provision for ventilation, and the Croydon sewers were subsequently ventilated upon the principle of bringing shafts up to the open streets, and fixing open ventilators there. It may also be stated that Croydon was as much astray in its water-supply and soil-pan arrangements as in its sewering. The cheap common soil-pan was used, having water laid on from the main by a pipe and tap at the soil-pan end. There was no interruption by a service-box, so that the tap, if left open, or was out of order and leaking, and a water pipe was emptied for any purpose, a vacuum was produced for the time, and if the pipe and tap at the soil pan was open, and the pan was full, excreta was passed direct to the water main. This said arrangement could, under the defective arrangements described, prove deadly, so that Croydon was unfortunate at first both in its main sewering, house draining, and water supply. In the beginning of the sewering of London, namely, from 1800 up to about 1835, large, square, flat-bottomed sewers were made, and ventilation was not provided. The result was a great prevalence of typhoid fever. The London, City, and parish authorities then made another mistake. This was in forbidding drain connection from houses having water-closets to the sewers. Cesspits and cesspools were then resorted to, and were multiplied by tens of thousands. They were formed in gardens of large houses, in back yards, and within the basements. The first Board of Health office at Croydon, now at Whitehall, was found to have nine within the basement, all full and overflowing. The sewers were then made into retorts of gases which produced typhoid fever, and the drains were the conduit pipes for carrying the gases into the houses. After this the London houses were ventilated by means of the street openings, hundred of which might be seen to this day. He had two examples, which were very instructive as to the necessity of preventing wind from blowing into the open outlets of main sewers. At Leeds a large sum of money was spent in sewering a portion of the town, and a large outlet sewer was

turned upon the banks of the river a mile or two away. This outlet was some 6 feet high and 4 feet wide, the mouth standing widely open, and facing down the river. At first the better class of houses in Leeds were connected with the new sewers. He held an official inquiry at the town as to certain local requirements, and, in going over the death-rate of Leeds with the chairman of the Works Committee, he found that, in proportion as the town had expended money upon their sewers, the death-rate had increased. After asking the chairman of the Works Committee whether he thought that this ought to be the case, he took him down to the end of the large outlet sewer and showed him the great staring mouth of the sewer fully opened, and told him that he had the evidence of the medical officer of health that, when the wind blew up the river into the mouth of the sewer, there was a more intense action of the sewer gases in the connected houses, which were of the better class and on the higher outskirts. He then directed that the outlet of the sewer should be closed, so as to positively and absolutely prevent the wind blowing in, and the local Surveyor of that day put man-holes and open-grate ventilators on the sewers, and untrapped the street gullies, the local medical officer soon finding a diminished death-rate. He conducted another experiment, much more interesting, because it was much more important. He was sent out by Her Majesty's Government to the Crimea to see whether anything could be done to bring about beneficial results with regard to the health of the wretched British army, which was suffering a rate of mortality greater than any on record. The mortality was greater than that which attended the retreat from Moscow. Of 33,000 of the finest men which England ever produced, 11,000 died in three months, December 1854 to February 1855. In February, 1855, the army sanitary commission left England and landed at Constantinople the 6th of March, and on the next day the great Turkish barrack hospital at Scutari was visited. This great hospital, situated on the Bosphorus, was the finest building of the kind in Europe, and had been handed over to the British army for hospital purposes. The rooms and corridors were crowded with sick and dying soldiers. Eighty or ninety bodies were buried out of that hospital every day. Upon the second day that the commission was there they caused the windows to be broken to let the air change, not by hundreds of cubic feet, but by millions. The commission was bitterly opposed by some of the army medical officers, for, I suppose, it was thought to be a great slight upon them for a sanitary commission to be sent out to deal with the condition of the hospital. The chief medical officer of the hospital of

Scutari protested that all had been done which could be done, and then stated that a change of wind, when it took place, sent fifty more men in that hospital into a worse state of fever than before. He (Sir R. Rawlinson) inquired at once of Captain Gordon, of the Royal Engineers, whether the building was sewered. Captain Gordon, being unable to answer the question, referred him to his orderly, who answered in the affirmative. The site of the hospital was situated 60 or 70 feet above the Bosphorus, and on a very steep bank leading down to the water, he found three big flat-bottomed sewers, about 6 feet by 4 feet, facing the sea of Marmora, and when the wind blew in from that direction, the men in the hospital went down with the worse type of disease. He at once saw that the entrances to the sewers must be blocked, and he designed a flap for the purpose. He was met with a shrug of the shoulders, and told that it was impossible that such flaps could be made. He then ordered some old tents to be cut up and fixed over the mouths of the sewers, and fastened down to the clay or marl bank; and he had openings broken down to the sewers immediately outside the boundary wall. The next afternoon he visited the hospital, and Captain Gordon told him that he was going to close the new openings up on account of the smell that came from them; but he (Sir Robert) refused to allow this to be done. The sewers were then trapped by an ordinary dip-trap, and a stage made upon which a large wine cask was placed and made into a flushing tank, to be filled by water carried up from the Bosphorus day by day, and this was continued to the end of the war. Sir Robert stated that the Easterns will not use a seated water-closet, but have a hole in the floor to squat over, water to wash with being supplied. He further stated that when the Sultan came over to this country, some years ago, and had the basement of Buckingham Palace apportioned to him and his attendants, the apartments occupied by him and his suite had to have the water-closets taken out and holes put in the floor, such as they were accustomed to use in their own country. No high caste native of India, much less the Sultan of Turkey, would allow his skin to touch anything which the skin of a person of a lower caste had touched. Hence, all through India our sanitary engineers have to provide something other than water-closets for the use of native princes. He (Sir Robert) believed that it was a gross mistake to provide water-closets for the low-class population in the east of London. The eastern mode, a hole in the floor, could be washed with a bucket of water, and there would be nothing for the people to break, and no apparatus to get out of order. But

in our old baronial castles, Windsor Castle for instance, there were turret towers having projecting corbels and a small space or recess inside, the flow being directed to an opening in the middle, the excreta falling outside to the foot of the turret tower. These places were known as Guarderobe Towers. They were found to have been in use in the olden times at Windsor Castle. His friend, Mr. McKie, had carried out the sewage of Carlisle, which was one of the earliest towns, if not the earliest, which had been completely laid with sewers proportioned to the work which they had to do. The outlet had to be somewhat larger, for it was a mile and a quarter in length, and was also outside the city, and had a gradient of one in a thousand. It was laid with an invert on the dead level of the low water of the river. The river on one occasion rose to 23 feet above that level, and of course blocked the sewer and put it under pressure; but all that had been provided for. The sewers of Carlisle were all graded down to suit the outlet, and he believed that at that moment not a gallon of real excreta sewage remained in the sewers of Carlisle for twelve hours, and that if the outlet of the sewer was inspected at midnight, and again at six in the morning, it would, he believed, be found to be running with clear water. One reason of this was that the subsoil and spring water were taken into the sewers as they were being laid. Mr. McKie had ventilated the sewers, and in carrying the system of ventilation out he entered into treaties with all the owners of tall chimneys to enable him to connect the sewers with those chimneys. That, of course, was a great advantage, although, at the same time, it would not do to depend entirely upon the chimneys, because the chimneys would draw air from anywhere, and it was utterly impossible to make the sewers air-tight. Before a sewer could be ventilated through and through it would have to be made like a colliery drift and have doors to shut off air from coming into it. The ventilation by means of the tall chimneys did not extend for anything like as far along the sewers as might be imagined. For this reason the street surface grates were employed *plus* the tall chimneys. In the Carlisle drainage the engineer had carried out the law which he (Sir Robert) had laid down, viz., that sinks must drain, not direct into the sewer, nor direct into the drain connected with the sewer, but into the open air above the mouth of the trap. Then vertical pipes must be carried up from the drains as ventilators. Such pipes ought never to be less than 4 inches diameter, and on a large house needed to be from 9 to 12 inches. Flues in walls of houses should not be used for sewer or drain ventilation as these would get foul and corrupt,

and could not be cleansed. Ventilating pipes and pipes from water closets should be outside and not inside, cased up or buried in brickwork. Means may be employed to produce an upward current in the ventilating pipes. Wealthy persons could afford to put a gas jet at the bottom in order to force a current, and that would be a very safe thing to do; but an upward current of air there must be by whatever means it was produced.

He would give them another instance of ventilation of a house sewer. Some ten or twelve years ago he was sent for by the Duke of Sutherland to go to Dunrobin, the Duke's residence in Scotland. The house had been built by Barry, and what drainage there was had probably been carried out under him. He (Sir R. Rawlinson) was sent for in the autumn on account of a stench throughout the house, which had occasioned the visitors to leave. When he arrived he found that the water-closets had been papered up, with the exception of one or two which the family were using. The house was drained by a large square rubble-stone built sewer having vertical shafts. The sewer had a steep gradient from the house to the sea. [The speaker made a sketch on the blackboard to show the position of the house and the course of the sewer.] When the sewer was built, shafts were made at intervals through it. They extended 8 or 10 feet below the bottom of the sewer, and 5 or 6 feet up to the surface of the ground. The shafts were supposed to be covered with slate, and no provision was made for ventilation. The clerk of the works, having found that some of them were leaking, had caused them to be hermetically sealed up with cement. There were nine or ten of the shafts, and he (Sir R. Rawlinson) had all the covers taken off them without saying anything to his Grace about what he was doing. He told the housekeeper to unpaper all the water closets, and to keep the windows shut, and to go round the house from midnight to two o'clock in the morning and tell him what she found. Her report was that the house was perfectly sweet and had never been sweeter before. In the morning he took his Grace out and showed him the arrangement which had caused the mischief, and told him that an open ventilator must be put on everyone of the shafts, that the pits in the bottom of the sewer must be cleaned out and then be filled in with quick lime concrete, and that the sewer must be carried through the base of the house and up to some high land behind, being provided with a vertical shaft which must be always open. Arrangements were made, by means of a flap, to prevent the wind or sea air from blowing in and up the sewer.

He had found the White House or lodge, just above Richmond Hill, in exactly the same condition as the Duke of Sutherland's. He ordered the same things to be done, and he had heard no further complaint. He had always maintained that a house or a town which stood on a steep gradient, such as Brighton or Liverpool was far more difficult to ventilate than a flat town because sewer-air was generally lighter than the atmospheric air, and rose upwards as the sewage gravitated downwards. Towns with steep gradients must be sewered in contour line zones and have intermediate means to ventilate the lower zone so as to break the continued upward flow of the gases. At Liverpool, at one time when there was no ventilation from the lower part of the town upwards, the mortality was regularly from 36 to 37 per thousand. At Brighton, when he went there more than thirty years ago, there were a few sewers, but no main sewer ventilation. He had the first manhole put down on the Hove at Brighton in order to show the authorities what he intended, and he was abused by some of the members of the Town Council, who said that they would take good care that there were none of those stinking things put in at Brighton. But, subsequently, when Brighton was sewered, the surveyor ventilated his steep sewers up the highest slopes that he could get, and built a shaft leaving the head fully open. That was the position of the Brighton sewers now. Liverpool had had its sewers continued up to high ground, an open ventilation provided at the top. Such ventilation was absolutely necessary. He might add regarding Brighton that in 1857, that town was in a most unsatisfactory sanitary condition. Standing on chalk, wells were easily sunk in this stratum the first wells sunk were to obtain water, the second set sunk were for cesspools and there were few sewers. The visitors required for their accommodation water-closets, and water was provided by a company before sewers had been provided, in many cases the wells from which water had been pumped were converted into cess-pits to receive the contents from water-closets; gastric and enteric fevers becoming common, the Town Council at length found out that Brighton could only prosper when a clean bill of health could be presented, and main sewering was decided upon. The main sewer of Brighton, commencing about the centre of the town on the sea shore at the level of high-water, is carried eastward at the foot of the cliff to low water, having been executed under difficulties at a cost exceeding 100,000*l*. This sewer is never empty, as the outlet can only be free occasionally for about half an hour. He must say in conclusion that he was very pleased to have heard Mr. Santo

Crimp's paper, which he should read very carefully. He begged to congratulate Mr. Crimp upon the appointment which he had obtained. He knew that he was the right man in the right place, and one upon whom he (Sir R. Rawlinson) felt that the London County Council might depend to carry out any works devised by his chief.

Mr. McKie said that Carlisle was the first to adopt the high chimney as a means of ventilating sewers. The tallest chimney which he had used was 305 feet high. He had two openings to that chimney, one having a 12-inch pipe and the other a 9-inch pipe. The anemometer registered about 50 miles an hour. The current was greater than that of any storm which he had met with on the Welsh mountains. The chimney was a large one, and had a door to it, and he put in a glass syphon to see what pressure there was in the chimney. He found that it only amounted to a pressure of water of $1\frac{3}{10}$ inches. Then he went to a gulley which he put down 81 yards away. That was not untrapped by any means, but he found a depression of about $\frac{3}{8}$ths of an inch. He then stopped up all the ventilators and covered in the tops of them, and he found that the chimney would draw about 400 yards from it, but it would not do so if the inlets close to the chimney were left open. He believed that the ventilation of sewers would be very simple if the sewers were made self-cleansing. He did not think that there would be any difficulty about ventilation when that was done, but if they were sluggish, and a fall could not be obtained, and if there was a deposit in them, then the engineer should try to ventilate as much as possible, but it would be very difficult to ventilate them perfectly. What he had heard this evening and what he had read had instructed him very much in that matter. He had calculated that in the Carlisle sewers the sewage, when the sewer was half full, was discharged at the outlet in thirty-six minutes from the Town Hall, and in an hour and eight minutes from the most extreme point of the town. If the contents of a sewer were discharged in two or three or even twelve hours, there would be very little occasion to ventilate. Since Carlisle, he had sewered a town in the north of England with very steep gradients. He had divided the town into 24 districts, all of which had steep gradients. Each district was cut off and sealed by ventilating syphons to prevent sewer air travelling from one district to another in the sewers. In the case of an epidemic, sewer air could not travel in the sewers from one district to another, thereby giving a greater command of localising and combating the spread of disease. A self-acting flushing chamber was placed at all the blank ends of the sewers.

That town had been sewered four years, and he had written to ask how the system worked. He had ascertained that to this day there had not been a single complaint about the ventilation. The ventilation consisted simply of surface manholes and nothing else. By reason of the rapid falls, the sewage was delivered at low water into the Solway from the farthest branch of the sewers, when running half full, at the north side of the river in twenty-seven minutes and at the south side of the river in thirty-two minutes. He would recommend that a system of sewage should be made simple to begin with, and developed afterwards if necessary. Engineers should not spend much in the first instance till they found that they had got the right thing. He did not know whether he had yet got the right thing in the town which he had last mentioned. Unquestionably very much light had been cast on the subject that night. In the cases which he had carried out by himself, and also in those which he had carried out under Sir Robert Rawlinson, the sewers had answered the purpose for which they were designed.

Mr. W. B. Tripp said that as far as he had heard that evening, successful ventilation depended more upon the state of the sewers than upon the particular kind of ventilator employed. If there was nothing offensive in the sewers there could be nothing offensive at the ventilators. He had lived in a district near the top of the higher levels of a sewer, and he had frequently found that the ventilators in that district became offensive. He believed, from his experience in sewer construction, that the reason of the offensiveness frequently was that the ventilators had to do more than their proper duty. Authorities had to deal with sewers as they found them, as had been pointed out that evening, but if the sewers were divided so that the ventilators did not have more than their proper duty to do, they could not become offensive. That appeared to be the result of the discussion as far as it had gone. He believed that the statement of the author that the wind had an immense effect upon sewer ventilation was very correct. In windy weather the effect of the temperature was very small. In calm weather the state of the dew point might have a considerable effect. If the sewers were judiciously arranged, and unless offensive matter were allowed to accumulate below the street ventilators, they need not become offensive, and he was very pleased to find that, in support of that statement, they had the authority of so eminent an engineer as Sir Robert Rawlinson.

Mr. H. A. Roechling said that Mr. Santo Crimp had referred

to a very important point with regard to the health of towns. In Munich very elaborate experiments had been made, and the investigators came to views rather opposite to those stated by Mr. Crimp. One set of experiments was made in winter, and one set in summer. Both sets were of comparatively recent date, the last set being made in 1881. The experimenters agreed on the following points:—(1) That the wind had practically no influence upon the movement of air in the sewers; (2) That the flow of sewer air was principally down hill, caused to some extent by the flow of sewage, and only on rare occasions up hill. On the question of the influence of the temperature they differed: the observer who made the experiments during the summer came to the conclusion that the temperature difference had little to do with the movement of sewer air, whereas the experiments made during the winter showed that this influence was considerable. He might further state that Berlin had been drained upon the principle of open surface ventilators, situated frequently in the causeway or close to it, and he had been informed by the chief engineer, Mr. J. Holrecht, that at first some few isolated complaints had been made, but since those had been remedied they had had practically no complaints whatever.

The Chairman said that if Mr. Roechling would kindly send the particulars in writing to the secretary the Society would be deeply indebted to him for them, and the council would see that they were printed in the Transactions.

Mr. Santo Crimp thanked the meeting for the very kind way in which they had received his paper. He especially thanked Sir Robert Rawlinson and Professor Robinson for the very flattering way in which they had referred to his appointment to the London County Council. Replying to the discussion, he said that Mr. Strachan's experiments entirely confirmed his. He would not say so with regard to the action of the wind, because he thought that they might take it as a proved fact that it was the wind which caused the movement of sewer-air. He did not quite share Mr. Strachan's fear as to the effect of turning the aerial contents of the sewers into the atmosphere above the roofs of the houses, for he did not see how the sewer-air could be injuriously affected by mixing sixty or more volumes of fresh air with it. On the contrary, the mixture of so much fresh air must tend to improve the sewer-air, and render it less offensive. He quite agreed with Professor Robinson that one system was not applicable to all cases. Every case should be dealt with upon its own merits. They all knew the advantage of flushing, but, where flushing had

failed to cure an offensive ventilator, a very simple and perfectly effective remedy was to run a ventilating pipe up the nearest high-reaching object. Sir Robert Rawlinson, in giving them an interesting account of his experience in various towns, had referred to Croydon. Last Saturday he (Mr. Crimp) was informed by an official in the office of the borough engineer of Croydon that, at the present moment, street ventilators were being abolished in the town, and ventilating pipes were being carried up houses, trees, or other convenient objects. There was some suggestion as to the outbreak of typhoid fever at Croydon being due to sewer-air, but his own impression was that the outbreak was, in some measure, due to the Croydon water supply. Death rates had been referred to, but they might be used in two ways. During the decade ending in 1880, Bristol had the lowest zymotic death-rate of all the large towns enumerated by the Registrar-General with the exception of Brighton, and, as they knew, the Bristol sewers were unventilated to this day. He mentioned that fact to show that death-rates were not conclusive evidence as to the advantages or disadvantages of sewer ventilation. He was glad to hear from Mr. McKie that the chimneys were being used for sewer ventilation at Carlisle, and it seemed to show that the street ventilators were not considered sufficient. He hoped that Mr. McKie would be as successful in many other cases as he had been in that of Carlisle. In Frankfort every house had to ventilate part of the sewer, and in Mr. Crimp's opinion every house should ventilate part of the system by which it was drained. His experiments at Wimbledon were made both in winter and in summer. He was very glad that it appeared to be admitted that their old friend "temperature" was dead. He was prepared with a large amount of information which he obtained at Margate, which entirely confirmed all that he had said about the effect of the wind, but no further evidence on that point was required. He had also made some experiments on the drains of new houses which had never been occupied, and he found that the air currents were very considerable when there was no sewage, provided there were rapid movements of the atmosphere. With regard to the London sewers the question was a large one, and he felt that until they were all placed under the central authority of the London County Council, their ventilation would never be in any degree perfect. He had had examinations made of the local sewers draining into the main sewers, and he had found that in many cases, where the local authorities had had complaints of smells from the ventilators of the local sewers,

they had blocked up such ventilators, and driven the air into the main sewers, and then said to the central authority, "Your sewers are an abomination; pray do something to ventilate them." He could only repeat that the ventilation of the London sewers must be dealt with in a comprehensive way if any really good result was to be attained.

Fig. 3.

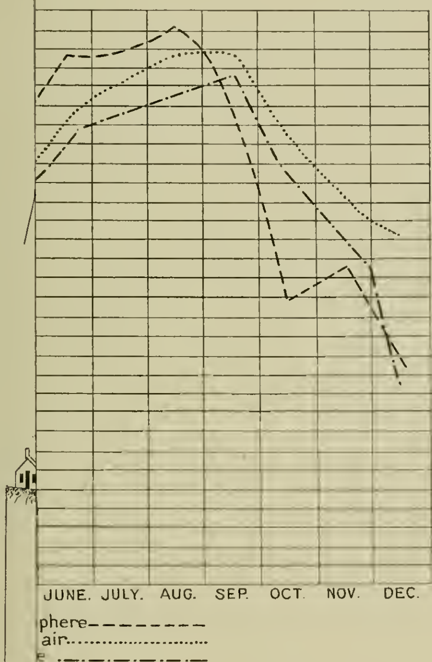
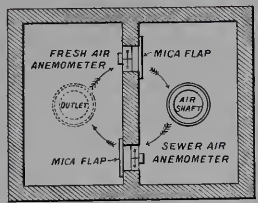
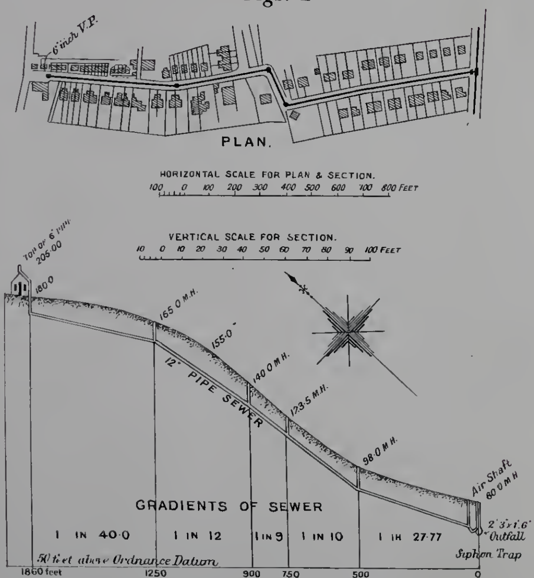


Fig. 1.

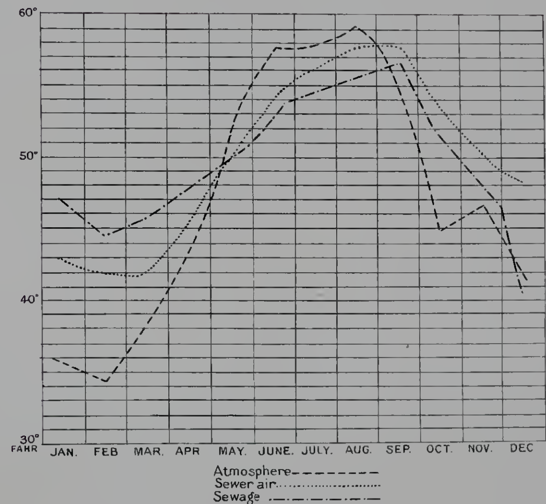


Figs. 2



SECTION.

Fig. 3.



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HENRY ADAMS, President, in the Chair.

ON THE TREATMENT AND UTILISATION OF EXHAUST STEAM.

By Percy Griffith.

The economical value of exhaust steam from all classes of engines is so considerable that no employer of steam power can afford to neglect it or to allow any portion of it to be wasted. It is, however, a fact, that in spite of the great number and variety of the systems at present before the public for its utilisation, comparatively little advantage is taken by engineers generally of the many purposes to which it may with economy be applied. The explanation of this appears to be that the subject is one regarding which but few practical data exist, and those which are available, consist chiefly of advertisements, circulars, &c., issued by the leading manufacturers and patentees of apparatus for utilising exhaust steam, a species of information which is subject to large discounts, and is liable to be either viewed with suspicion or rejected as worthless by the majority of engineers who read them. The author, therefore, hopes that by a paper devoted to this question he may be able to direct attention to some interesting features of this important department of engineering, which may hitherto have escaped notice.

Speaking generally, the uses to which exhaust steam may be applied, are three in number:—Firstly, for heating water; secondly, for condensation to form a vacuum; and thirdly, for evaporation to produce distilled water, or to concentrate liquors or juices.

Firstly, for heating water:—Under this head, the application of exhaust steam to heating the boiler feed-water is certainly that part of the subject which has been most fully investigated, both in theory and practice; but it is not by any means the only point to be considered in this connection, as will be shown in the course of this paper. The fact, however, that in most

cases its application to this purpose secures the preservation of the boiler, together with a certain economy of fuel, entitles it to the first place among the uses of exhaust steam for water-heating; it is, therefore, proposed, first to examine in detail the advantages obtained by this very simple and common expedient, and afterwards to refer to several types of feed-water heaters in common use.

Among the advantages of feed-water heating, the most patent, although not the most important, is economy of fuel. The actual proportion which this bears to the total amount of fuel consumed can be roughly defined by the following calculation, viz. :—Take the instance of a heater raising the feed water from 52° F. to 212° F., and a boiler capable of evaporating 10 lbs. of water per pound of fuel and using 500 lbs. of fuel per hour, and consequently evaporating 5000 lbs. of water per hour. As 160 units of heat are required to raise 1 lb. of water from 52° to 212° F., the amount of heat required for 5000 lbs. is $5000 \times 160 = 800{,}000$ units; taking 1000 units as the amount required to evaporate 1 lb. of water at 212° F. and dividing this number into the units required for heating 5000 lbs. of water, viz. 800,000, the result 800 represents the weight of water which would be evaporated by this amount of heat, and the boiler evaporating 10 lbs. of water per pound of fuel, 800 divided by $10 = 80$ lb., which is the equivalent weight of fuel consumed in heating the water from 52° to 212°; thus, while 500 lbs. of fuel are consumed for evaporating, 80 lbs. of fuel are saved by using exhaust steam to heat the feed water, this being equal to 16 per cent. of the former amount.

The other advantages of feed heating will, however, if taken together, often exceed in value this one item, and careful attention should always be given to them. They depend chiefly upon the diminution of scale in the boiler, and therefore their actual value varies according to the character of the feed water employed. They may be classified as follows: greater safety and lengthened life of the boiler, and the avoidance of periodical chipping of the scale from plates and tubes. The immediate cause of this diminution of scale in the boiler is the precipitation of the carbonate of lime or temporary hardness (which is contained to a greater or less degree in all town water supplies) in the heater instead of in the boiler, where it can easily be got at and removed without blowing out the boiler or stopping the machinery. It has further been found by analysis of the deposit in the heater that some portion of the sulphates or permanent hardness is also precipitated, although the manner in which this is brought about is not clear.

Another point worth special mention is that by supplying a

hot feed instead of a cold one the enormous racking strain on rivets and plates, owing to the difference in temperature between the top and bottom of the boiler, is greatly reduced, and repairs to joints or annoying leakages are consequently much less frequent. The increased power of the boiler, owing to a supply of hot feed water, is also an important consideration in cases where, otherwise, an additional boiler would be required.

When it is remembered that all the foregoing advantages can be secured at no greater cost than that of the heater itself and the necessary connections, the steam being otherwise wasted, it will be seen what value the exhaust steam possesses when applied to heating the feed water alone; but it must be here observed that as the feed water cannot condense more than a small portion of the exhaust steam, the remaining steam is still available for other purposes.

Bearing in mind these various duties which a feed-water heater is able to fulfil, it will be easier to form an opinion as to the type of heater most suitable for the adequate performance of them. Thus, a vertical heater with the water in the outer casing is preferable to a horizontal one with the water passing through the tubes, as in the former case the speed of the water is comparatively small, and the precipitated sediment has a better opportunity of being separated from the water; also in a vertical casing the falling sediment accumulates in its fall, and thus acquires additional weight to carry it down to the bottom. From the foregoing it follows that, as the heater acts, or ought to act, as a collector of impurities, ample provision should be made for removing the deposit at frequent intervals, and hand-holes sufficiently large, easily accessible and conveniently placed, should always be provided.

In order to secure continued efficiency of the heater, care must, however, be taken that the tubes are kept free from scale. This may easily be done by means of a strong jet of cold water thrown on to them sufficiently often to prevent the accumulation of the scale to any appreciable thickness. If this point be neglected, the tubes will probably, after a few months working, become coated with a jacket of scale, which, although it will not stick to the tubes owing to the difference in the expansion of the metal and that of the scale, will greatly impede the transmission of heat, and consequently will impair the efficiency of the heater.

Referring now to the diagrams representing simple feed-water heaters, Fig. 1 is a section of the "Dudley" heater, made by Messrs. Sheppard and Son. This is generally arranged vertically, although it can be fitted horizontally when the

purification of water is not essential. The steam entering the lower chamber rises up the smaller internal tubes (of wrought iron) by which it is discharged into the closed ends of solid-drawn brass tubes of larger diameter. Thence it travels down the annular space between each pair of tubes, and the remaining portion is discharged at the outlet shown. The condensed steam is collected at a small outlet provided for it, and a relief valve prevents any accumulation of pressure from affecting the engine. A special feature of this heater is that the steam is practically delivered into the top of the water casing, thus acting first on the hottest water. The author, however, is by no means sure that this is more satisfactory than putting the steam into contact with the coldest water first, as is more generally done. The water passes upwards from the inlet to the outlet shown, where by means of the pipe dipping into the water any floating scum is arrested in the heater.

Fig. 2 shows a heater made by Messrs. Caird & Rayner, which presents some peculiar features. It is usually arranged to fix in the run of the exhaust pipe; the steam, therefore, enters the casing at the bottom, and that uncondensed passes away at the top. The water enters the tubes at A, passes by a pair of volute coils to the centre, where a brass casting connects this pair to another pair above, through which the water passes again to the circumference. Here a similar brass casting connects to a third pair of coils, and the water is again carried, as at first, to the centre, and thence to the circumference at outlet B. A drain is provided for the condensed steam, which is not shown on the diagram.

A weak point in this heater appears to be the liability of the tubes to become choked with the sediment which would be very difficult to remove; and if it be urged that the rapid motion of the water prevents this, a most important function of the heater, as a scale arrester, is neglected. It has been pointed out, however, that where the water purification is important, a duplicate heater can be provided at small cost in which the water, after leaving the first, shall be passed through the casing instead of through the tubes, live steam from the boiler being supplied to the coils, and these being drained to a steam-trap. In this second heater, although it is very doubtful whether any economy is derived from the increased temperature of the feed water, it is certainly the case that the purification of the water is more complete than in any exhaust heater.

Fig. 3 shows the construction of Messrs. Kirkaldy's "Compactum" heater. Steam enters at the inlet marked 1, and passes through the tubes to the outlet 2, while the water enters at 3, passes vertically up the casing, and is taken off at outlet 4.

The other fittings shown on the diagram are, scum valve at 5, drain and sludge cock at 6, relief valve at 7, soda cock at 8, and drain from tubes at 10.

Fig. 5 shows an improved form of the Berryman heater, introduced by Mr. Joseph Wright. The construction of the upper part is no doubt familiar, and can be understood from the diagram without further description. The improvement consists in the grease extracting apparatus contained in the lower portion of the heater. The object of this apparatus is to render the steam which is condensed in the tubes fit for boiler feed, by extracting from it the oil which is carried over from the engine. Most animal oils decompose at a temperature of from 200° to 300° F.; consequently, if these are pumped into the boiler, the fatty acids into which the oils dissolve attack and seriously injure the plates and tubes, while even pure mineral hydro-carbon oils, which do not decompose under a temperature of 600° F., will, if constantly fed into the boiler, accumulate and gradually reduce its steaming capacity. The separation of the oil or grease is affected in the following manner. The condensed steam is collected in a central tank, from which it overflows at B on diagram into the outer tank. Fresh cold water admitted through a ball valve to the tank shown on the left of the diagram passes through the tube A A into the lower part of the right-hand tank, and at this point it causes the greasy matters tc congeal and float on the surface of the water, where they are skimmed off automatically by means of an overflow pipe provided for the purpose. To prevent this floating scum being drawn off by the feed pump, that is, should the water level ever fall to the suction outlet S, a special standpipe is fitted inside the tank, as shown in section. This causes the feed-water to be always drawn from near the bottom of the tank, and in the event of the water falling, by any accident, level with the suction outlet, the pump at once draws air through the top and open end of the stand-pipe.

The feed water, having still to pass through the outer casing of the heater, is further purified in so doing, and any floating scum in the casing is excluded from the feed pipe by the dipping pipe at the crown of the heater. The diaphragm plate, dipping into the centre of the middle tank, prevents any back-pressure being thrown on the engine by allowing the steam, in the event of any increase of pressure, to blow through underneath it, and thence direct into the outlet. The taper cylinder, dipping half way down into the central tank, prevents the steam in this case from blowing out into the suction tank.

While dealing with this part of the subject, a passing reference may be made to feed heaters using live-steam in-

stead of exhaust, of which Figs. 4 and 9 are illustrations. Fig. 4 is a section and elevation of Kirkaldy's "Compactum" live-steam heater, in which the steam is admitted to the tubes at 1; water enters either at 3 or 4 and passes out at 2; the condensed steam is carried from outlet 5 either to the water space of the hotwell when the engines are condensing, or otherwise to the suction tank, while the air liberated from the steam is carried from 6 to the hotwell air space or to the open air. Top and bottom stand-pipes are shown at 7 and 8 respectively, and soda cock is shown at 9.

In contradiction of what seems a self-evident theory (viz. that no advantage can accrue from using live steam to heat the feed water) Messrs. Kirkaldy publish a long list of individual cases in which the economy of fuel obtained in this way averages over 1 ton per day, and although the reason of this is not very clear, it may probably be due to the increased purity of the water secured by the higher temperature in the heater.

The heater shown on Fig. 9 is worthy of special notice, owing to the peculiar method under which it is worked. The system was introduced by Mr. Weir in the year 1871, and consists in heating the feed water by direct contact with steam taken from the low pressure or intermediate receivers of compound or triple expansion engines respectively. The steam pipe is connected to the heater at A, where an automatic valve regulates the supply according to requirements, and prevents the water from returning to the receiver. The steam, passing round the annular space BB, enters the centre part of the heater through the perforations shown. The water, admitted at C through an adjustable valve, falls in a spray upon the rising steam, while any air liberated from the steam is carried off through the air-vessel D. The condensed steam and the water fall into the lower part of the heater, and are drawn off by a special pump, the speed of which is regulated by means of a float acting on levers, which control the throttle valve on the steam supply. As the claims of this system to economy and efficiency are beyond the scope of this paper, the author does not propose to enter into them, but since they are well worthy of the attention of engineers, reference may be made to a small book, entitled, 'Terrestrial Energy,' written by Mr. James Weir, and to an article published in 'Engineering' of May 2nd, 1890, by Professor J. H. Cotterill, F.R.S., entitled, 'Notes on Feed Water Heaters,' in both of which the subject is clearly dealt with.

Returning to the various uses of exhaust steam, there is one very important branch of this subject which has not hitherto received the attention it deserves, viz. the use of

exhaust steam for heating water required for baths, lavatories, or in heating buildings. The Patent Heater Condenser Company have recently erected extensive plant for these purposes at several hotels and large buildings in London, amongst others at the Victoria, Métropole, and Savoy Hotels, the National Liberal Club, Whitehall Courts, and Mr. D'Oyly Carte's new theatre. In these cases plenty of exhaust steam was available from the electric light engines, which, being non-condensing, would otherwise have wasted the greater part, if not all, of the steam exhausted from them. Many manufacturing firms requiring hot water in large quantities for trade purposes have also adopted plant to utilise exhaust steam in this manner, some even converting condensing engines into high-pressure engines in order to obtain a sufficient supply of exhaust steam. The economy of this will be seen when it is remembered that, by erecting auxiliary boilers to produce the hot water required, a considerable proportion of the heat generated by the fuel would be wasted up the flues, and by leakages, &c., while in a heater the whole of the heat contained in the exhaust steam can be transmitted to the water, and thus no waste occurs at all. This consideration alone often justifies the use of high pressure rather than condensing engines, but in London and other towns, where circulating water for condensing is expensive and difficult to obtain, the economy of this proceeding is doubly apparent.

The second part of the subject, viz., the condensation of exhaust steam to form a vacuum, is so thoroughly understood and appreciated that the author merely proposes to call attention to Fig. 6 in connection with it. This diagram illustrates a novel form of condenser recently introduced by the Patent Heater Condenser Company, which is based upon the principle of the Berryman water-heater. The addition of the U tubes in the bottom chamber is practically the only alteration in general design, but the application of this model to use as a condenser presents some peculiar features. Being vertical, a much smaller floor space is required than in ordinary forms of condensers; the arrangement of tube area allows a more perfect absorption of heat from the steam by the circulating water, and thus a less quantity of the latter is required. The action of the tubes in the lower chamber is also worthy of notice. The condensed steam falls from the upper tubes into the lower ones, overflowing through small slots in the projecting ends, where it falls as spray among the uncondensed vapour which descends the outlet on the (left) side of the upper tubes. Owing to the water in the lower tubes being in contact with the coldest circulating water, the inlet for the latter being in the lower chamber as

shown, the temperature is kept very low, and the injected spray from these tubes effectually kills any steam vapour previously uncondensed in the upper tubes. Another effect of this arrangement is that the water drawn off by the air-pump and delivered to the hotwell is also at a comparatively low temperature, from which it follows that a better vacuum is obtained, and the valves of the air-pump are less liable to injury and rapid wear, besides being more certain in action. Again, as a condenser of this type should never be erected without a feed water heater, the temperature of the feed water does not suffer on account of the low temperature in the hotwell.

The third part of this subject, viz., the use of exhaust steam for evaporating water or other liquids and juices, has only recently received any considerable amount of attention, the sugar industry being almost the only case in which exhaust steam has been applied to this purpose, and even here it is done at the expense of from 5 to 10 lbs. on the square inch back-pressure on the engines. In almost every other case live steam from the boiler is used for evaporating and concentrating, and reference may be made here to two or three forms of apparatus for this purpose.

Messrs. Kirkaldy, Limited, make an evaporator which is shown on Fig. 7 in elevation, and on Fig. 8 in section. In this the steam tubes are arranged in the form of vertical spirals, there being four or more in each evaporator. The ends of these tubes are connected at the top and bottom respectively to two circular bent tubes, which form the inlet and outlet pipes for the steam. The water is supplied to the outer casing through an automatic valve, which maintains a constant level, while the vapour is led off from the top to the condenser.

Another form of evaporator shown on Figs. 15 and 16 is that made by Messrs. Caird and Rayner. This is also vertical, but the steam is passed through tubes placed in the lower part of the casing and arranged similarly to those in their heater, i.e. the steam passes from the inlet to the centre, and back to the circumference by volute coiled tubes. As in Kirkaldy's evaporator the vapour outlet is connected to the condenser, and as ebullition takes place under a vacuum (say of 9 lbs. per square inch), a temperature of 170° Fahr. is all that is required to produce it, and further, as the water supply is drawn from the circulating or injection water in the condenser, and is therefore already at a temperature of about 100° Fahr., an additional 70°, plus the latent heat, is all that is required from the steam to cause evaporation. A feature of Rayner's evaporator is, that by breaking one joint, the whole of the tubes can be removed for cleaning, as is shown in Fig. 16, although if

the sludge or brine be frequently blown out this is very rarely necessary, the tendency of the tubes to straighten out under pressure preventing the adhesion of scale to them. The water supply to this evaporator is also automatic, this being a very essential condition of efficiency in all evaporators where sea or impure water is used for evaporation, for the reason that in the event of the evaporator, by any accident, filling with water, the condenser would immediately draw this water over, and it would be fed into the boiler, and would interrupt the working of both evaporator and condenser.

A more modern form of evaporator is that known as the "Yaryan." This is a horizontal casing into which the steam is supplied while the water is led alternately backwards and forwards in horizontal tiers of tubes at a very rapid pace. The vapour and concentrated brine or sludge are collected and separated in a special chamber fitted to the end of the casing. It is claimed for this apparatus that twice the duty per unit area of surface is obtained over any other form of evaporator, and it certainly does possess several characteristics which are worthy of special attention.

An exception to the use of live steam for evaporating purposes is the system introduced by Mr. James Weir, and which is similar to that adopted in his heater, viz., the steam is taken from either the low pressure or intermediate receiver of the engine. A front elevation of the evaporator is shown on Fig. 10, and a section on Fig. 11. It is arranged horizontally, and the steam passes round a series of horizontal U tubes, which are drained by a single U tube as shown, connected to the outlet and drain cock. The vapour is collected in a slotted pipe as shown on the section, and is thence led either to the low pressure receiver, when the steam supply is taken from the intermediate receiver, or to the condenser, when the steam supply is taken from the low pressure receiver. Objection has been raised to this system on the score that should the water by any accident fill up the evaporator, it would, in the first instance, be carried direct to the low pressure cylinder, and a breakdown would inevitably follow, while, in the second instance, it would be drawn into the condenser and be delivered to the boiler, as was before suggested.

With reference to evaporation for the purpose of concentration of liquors and juices, this has been principally applied to the manufacture of sugar, and a very complete treatise on this subject has recently been published in the 'Engineer,' written by Mr. James Hudson, M. Inst. C.E. It is, therefore, not proposed to enter into the details of this application of exhaust or live steam.

The principal use of the foregoing, and in fact of most forms of evaporators, is for making up the feed water, in connection with condensing engines, which is lost by leakage, &c., in order that the whole of the feed shall be distilled water and the addition of sea or impure water to that in the hotwell rendered unnecessary. The only system, however, which to the author's knowledge, at the time of writing this paper, applies exhaust steam exclusively to this purpose, is that recently introduced by Mr. Joseph Wright, and the combination of apparatus is shown on Fig. 12. The basis of this system is that while the steam from the main engine or engines is led to a condenser, the exhaust from auxiliary engines, such as the air, circulating or feed pumps or electric light engines, as the case may be, is led through a feed water heater, the steam uncondensed there is led through an evaporator, or a series of evaporators if required, and produces the necessary make-up feed in them, the steam being completely killed or condensed in the operation. Referring to the diagram ; the condenser, similar to that shown on Fig. 6, receives the steam from the main engine or engines, and owing to its being a surface condenser the water drawn off by the air-pump and delivered to the hotwell H.W., is condensed steam only, or in other words, distilled water. From the hot well this water overflows into the suction tank of a feed water heater, such as was described in connection with Fig. 5, where the greasy matter from the engines is congealed and skimmed off. Into the same tank falls the steam condensed in the heater and evaporator, and these together are delivered by the feed pump to the boiler through the casing of the heater. Meanwhile the exhaust from the auxiliary engines is led by the pipe F to the tubes of the heater, from which the uncondensed portion is taken direct to the tubes of the evaporator. A section of the evaporator is shown on Fig. 13, and an elevation on Fig. 14, from which the working will be sufficiently clear. The vapour from the evaporator is led (see Fig. 14) direct to the inlet of the condenser in which it is condensed and added to the water supply to the hotwell. Various valves and fittings are arranged in connection with the apparatus, to render it entirely automatic in action, which are not shown on the diagram, viz., automatic valves to admit live steam to the heater and evaporator, should the auxiliary exhausts be insufficient to provide the necessary amount of make up feed, automatic gear for regulating the speed of the circulating feed and air-pumps, where these are separate from the main engines, relief valve at D to allow any excess of steam in the evaporator to escape, and a tank with valve, &c., at E, to maintain a

constant level of water in the evaporator. This supply is taken as shown, from the circulating water outlet of the condenser.

In all ordinary cases of make-up feed, a single evaporator as shown on Fig. 14 is sufficient, but in manufactories where steam is taken from the boilers for other purposes than for driving engines, or is in any way rendered unfit for use with the auxiliary exhaust, that is for return to the boiler as feed water, a triple effect may be necessary to produce the amount of make up feed required. This may be employed with economy where the exhaust steam is at atmospheric pressure, that is at a temperature of 212° F.; thus, taking the vacuum in the condenser as 12 lbs. on the square inch which represents a temperature of 137° F., the total difference, 212 minus 137, amounts to 75° F., and dividing this among the three evaporators, the temperature difference in each will be equal to 25° F., which is found to be most economical in practice. Figs. 13 and 14 are shown connected together for working as double effect.

The evaporators may, of course, be used in cases where there is no condenser attached to the main engines, in which case a special condenser is required to kill the vapour formed in the evaporators, and under these circumstances jet condensers are sufficient for the purpose, and are of course cheaper than surface condensers.

In conclusion, the author desires to thank those gentlemen whose systems and apparatus he has referred to or described for the very valuable assistance they have rendered to him in the preparation of this paper.

Since writing the paper the author has received a description of an apparatus, somewhat allied in principle although very different in construction to that illustrated in Fig. 12.

This is shown on Fig. 17 in elevation, and on Fig. 18 in section. The apparatus is made by Messrs. Kirkaldy, Limited, and the three distinct parts are on the model of the "Compactum" heaters, &c., which have already been described and illustrated in Figs. 3, 4, 7, and 8. As in Mr. Wright's combination of heater, evaporator, and condenser, the exhaust steam, at or slightly above atmospheric pressure, enters the evaporator at A, passes through the S tubes, and is thence led to the tubes of the heater. After traversing these the remaining steam is carried to a cooler or condenser where it is completely killed. The vapour formed in the evaporator joins the exhaust steam between the heater and the cooler and is also completely condensed. The water of condensation is led to the

hot well of the main condenser or to the suction tank. The feed water enters the cooler at C, passes through the outer casing of this and of the heater, and is thus delivered heated to the boiler. The cast iron boxes at inlet A and outlet B are filled with small coke, and the steam passing through the first and the water of condensation through the second, are thereby cleansed of the oil carried over from the engine.

The apparatus, as will be seen, is applicable to purposes very similar to those referred to in connection with Fig. 12, viz., for utilising the steam from auxiliary engines, for heating and supplying the make-up feed water; but the author is doubtful whether the feed water alone would be sufficient to condense the steam from several auxiliary engines in addition to the vapour from the evaporator, also whether the condensation could be completed without an air pump.

It will be seen from the diagram that the vapour from the evaporator is led direct through the steam pipe into the cooler, and consequently the tubes of the evaporator and the vapour space of the same are practically in communication with each other. This being so, it is open to doubt whether a sufficient temperature difference could be maintained between them to produce evaporation in the evaporator either with or without an air pump.

DISCUSSION.

The PRESIDENT said that in every engineering and industrial operation the utilisation of bye-products was an important matter. In the case of the steam engine, the exhaust steam was in many cases a waste product. The author had shown several means of utilising it and although he might have referred to other methods, he had placed before the meeting ample material for discussion. He (the President) had to propose a hearty vote of thanks to the author for his paper, and for the numerous diagrams by which it had been illustrated, and on this motion being put to the meeting it was unanimously passed.

The AUTHOR, at the request of Mr. Schönheyder, gave a further explanation of the apparatus shown in diagram No. 6.

Mr. SCHÖNHEYDER said that the author had referred to the saving of one ton of coal a day, by means of the Kirkaldy apparatus, as if it was something very considerable; but the importance of the saving of that quantity would very much depend upon the size of the apparatus itself. It would be a very small saving for a large apparatus, but for a small apparatus the saving of a ton a day might be of very great importance. Perhaps the author would inform them as to the

size of the apparatus or the total quantity of coal consumed. As to the apparatus in the first diagram on the left, he believed that Perkins was the first to introduce a condenser of that kind with one tube inside the other. The arrangement was very neat, and the object was to avoid trouble from the expansion of the tubes. He did not think that there would be any benefit in having the hot steam going to the top, because the steam was practically at the same pressure and the same temperature all through the tube. No doubt some water of a slightly lower temperature would fall down the sides of the tube. Part of the arrangement in Kirkaldy's feed heater as shown in Fig. 3 and Fig. 4 seemed to be a great mistake. Air was heavier than vapour, under the same pressure and temperature, by about 60 per cent., and if the vapour in the condenser was sufficiently quiet, the air would accumulate at the bottom, and unless it was drawn away from the bottom the apparatus would work very inefficiently. In a vertical air pump of a common engine the water was drawn away from the lower part of the condenser, but the air was also drawn away from that part. If the water only were drawn away from the bottom and another pump was used to draw the air away from the top, there would not be nearly so great a vacuum. He failed to understand the condenser shown in Fig. 6. If the proportion was the same as shown there, the velocity in the tubes would be so great that the steam condensed would be carried forward and carried over to the other side. With reference to the lower U tubes as represented, there must either be a very considerable head of water at the right hand side or else the upper tubes must be so small as to considerably throttle the steam and cause an excesss of pressure on the right hand side. He would ask the author to state whether he ever saw such an action as that described or whether he could obtain information regarding it, from the makers. Certainly there could not be any kind of jet arrangement unless there was a high pressure on the right hand side of the U tubes to force the water up. As to the "Yaryan" evaporator to which the author referred, it was very unfortunate that there was no drawing and no statement as to the actual duty of the evaporators. He had heard a great many vague statements about what they were to do. The paper would have been much more valuable if it had contained statements of the amount of steam condensed or the amount of water heated, and the temperatures in the various apparatus described. Members would then have been able to form a better idea of the relative value of the different kinds. He thought that the author had very properly stated with reference to the condenser shown in diagrams 17 and 18 that

he doubted whether it would work. There must be a considerable difference in pressure between the steam in the S coil and the steam in the evaporator itself. The pressure in the evaporator must be considerably less than inside the tubes. That being the case, no steam would pass down through the pipe and into the steam space of the cooler; or the passing would be very much checked unless there was a considerable difference of pressure between the steam at the pipe and at the outlet down at the bottom B. They had not been favoured in the paper with any kind of statement as to the success of that apparatus.

Mr. Fortescue Flannery said that he agreed with the statement of the last speaker that they ought to be very much obliged to the author for bringing so much information before them; but if the result of the working of the apparatus had been also shown in detail comparatively, it would have been very much more to the advantage of those who had come to the meeting. He observed that the engineer-in-chief of the P. & O. Company, who had had as much experience in all classes of evaporators as anyone, was present, and he hoped that that gentleman would give the meeting some of the results which he had observed in his steamers. As regarded the Yaryan evaporators, he (Mr. Flannery) had also heard much asserted as to its advantages. It worked by spray, that is to say, sea water from which the vapour was raised was introduced in the form of spray, and the effort of that water being in the form of spray was to cause, in some unknown manner, a wonderful amount of comparative economy, and to prevent the deposit of salt upon the tubes. He should like anyone who had a knowledge of that evaporator to say why the introduction of the sea water in the form of spray prevented any deposit of scale. He could not understand why it should be so, but practice was far better than any amount of reasoning upon such matters. As to the evaporator spoken of by Mr. Schönheyder, he dissented, with great deference to that gentleman's opinion, as to the action not taking place in the manner expected. He (Mr. Flannery) thought that the pressure of steam upon the inlet on the right hand side would cause so much flow both downwards and upwards that there would be no stagnation whatever in the bent tubes at the lower side. If it was a mere question of equilibrium or of difference of weight, it might be otherwise; but he thought that the actual steam pressure and impetus, similar to that present in an injector, would be quite sufficient to cause the circulation which the inventor intended. The mode of utilising the coolness of the circulating water to make a cold jet as a means of contact with

the vapour that was not condensed in the upper tube, was a very ingenious and very practical arrangement. The only objection that he could see to it was that the inner pipes were so much embedded and shut-in by the outer pipes that there would be very great difficulty in cleaning them. There did not appear to be any means of taking them out readily. In this respect there was a great advantage in Rayner's & Kirkaldy's apparatus and those of one or two other makers. This point was as important as any other from the point of view of practical superintendence. He had observed almost every kind of evaporation, and if thought desirable he would be able to supplement his remarks by forwarding in writing to the society some of the results recorded in his notes at home.

Mr. G. W. Manuel said, that as far back as 1879 he had a little experience of feed heating, but at that time the apparatus was not so perfect as the appliances which now existed. He had very great difficulty in finding out what percentage of gain he got from its use. The evaporator had been tried from time to time during some years, for periods of two days on and two days off, a careful register being kept, but he was never able to say that so many tons of fuel per day had been saved. Perhaps these failures to get definite results were due to something that had been omitted in the experiments, which were entirely of a practical nature. He was very pleased to have been present at the meeting, and to have an opportunity of seeing all those improved evaporators and heaters which had been represented, but he regretted that no definite results from the different apparatus had been stated. They wanted information in the following form, viz., the temperature of the feed entering the feed heater, the temperature of the steam entering the feed heater to raise the temperature of the feed water, the number of degrees to which the feed was heated in consequence, and the actual saving of coal as compared to working without the feed heater, with the engines exerting the same power. If they had the information given to them in that form, they would be in a better position to advise owners or others to adopt any particular system of feed heating. His experience of evaporating salt water, to make up losses in marine engines, by special apparatus, had been of very short duration. He might say that he was more partial to the system of evaporating by high pressure steam, than by low pressure attached to the main engine condenser, similar to that shown by Messrs. Weir's drawings, and which was fitted to one of the P. and O. Company's steamers, both as regards efficiency and economy. It was also easier controlled by the engineers.

Mr. W. Worby Beaumont said that the author had begun by

telling them that very little was known about feed water heaters, but the numerous apparatus shown in the diagrams were evidences against the correctness of that assertion. What struck him was the great harmony which must exist among the makers, for some seemed to be direct copies of other's designs, and nobody seemed to object. He noticed, as the last speaker had remarked, a great absence of detail in the paper, and of particulars on essential points. The author had stated that one system of apparatus effected about double as much saving as another. But inasmuch as they had not been informed what that other effected, the statement did not give them much information. It was important to get people to see that in throwing away exhaust steam they were throwing away money, but it was not well to make people expect to get more saving from an apparatus than it was really capable of effecting. For instance, the author had told them that they would get something like sixteen per cent. of saving, but it appeared from the figures which he had put forward that the utmost possible saving would be about twelve per cent.; and, inasmuch as a very large reduction would have to be made from that, it would be better to lead people to expect only about ten per cent. instead of sixteen per cent. The rough rule which gives one per cent. saving for every ten degrees rise in temperature of the feed gives too high a result. He thought that the author had hardly said enough with regard to the advantages of the various feed heaters, for there were really very great advantages, apart from the mere saving in fuel. For instance, he very much doubted whether many modern high-pressure boilers could be worked successfully for any length of time if it were not for heaters in some form or other. Economy of fuel entailed a great many attendant advantages. There was no question that if they could burn less fuel the boiler would have to do less work in producing a given result, and therefore it would last longer and require fewer repairs. In connection with this point he was reminded of the scaling and grease-extracting which feed heaters might do. The feed heaters should be arranged so that in all cases they might be used to heat the water when the engines were not at work. For instance, the water might be heated by means of a donkey boiler, or something of the kind, and the water forced through the heater. Otherwise the advantages of the feed heater might be lost if the boiler was filled up with cold water, especially soon after being cleaned, and steam was then hurriedly got up. It seemed to him that the extraction of grease was a question worthy of serious consideration, and was a very important function of a heater. It was highly desirable, therefore, that the heater should be so

made that all the internal parts could be very readily got at and cleaned. It was also very important that if such an apparatus was to do its work economically the surfaces should be so constructed that the tendency should be that they would clean themselves to a very considerable extent. Among the heaters represented in the diagrams there were several which used worms or coils in different forms, and it seemed to him that these were really very valuable in the sense that they could move freely, so that it was quite impossible for a hard incrustation to form upon them. One arrangement shown for the removal of grease was ingenious, but he supposed that in most cases, by filling the heater and putting in a certain quantity of soda, and turning the steam into it, the water could be boiled up, and the grease washed away. The author had mentioned the superiority of the result obtained when the steam was admitted to either one or other end of the heater. He (Mr. Beaumont) thought that that was a question which depended upon whether the apparatus was a heater, or a condenser for obtaining water for drinking, or an evaporator. If the object was to heat the water the probability was that the greatest temperature would be obtained by putting the steam into the end of the apparatus from which the heated feed water was passing. If, on the other hand, they wanted to get condensed steam, just the opposite thing would be done. Again, with regard to the evaporator, the steam should enter where the water was at the highest temperature. With regard to the efficiency of the evaporators, a number of experiments which he had made with plain tubes, and corrugated tubes, and coil tubes, led him to the belief that they might get almost any relation between steam condensed and water used to condense it. In any given form of heater the question really depended upon the quantity of surface which they had at disposal. That involved the amount of traverse both for the steam to be condensed, and for the water to do the cooling. Then the question was what was the best heater from that point of view, and which one had the largest quantity of heating surface or of cooling surface within the space that it occupied. The author did not say how much heating surface there was in any one of the condensers. Probably there would not be very great difficulty in obtaining the particulars, and the information would very materially add to the value of the paper. On one occasion he (Mr. Beaumont) made some experiments with a heater fitted with Mr. Kirkaldy's coiled and corrugated tubes, with a view to ascertain the quantity of steam that might be condensed with a given quantity of water, and he found that in a vessel about six feet long with a very great length of traverse for the steam inside the coiled tubes, he could condense ten

pounds of steam with a little over ten pounds of water. The water used for condensing was all evaporated. It would thus be possible to heat to about 210° a large part of all the feed water for a boiler by the exhaust steam from a non-condensing engine. That bore upon a point which the author had mentioned concerning the heater which was shown on Fig. 16 with three vessels, one superposed upon the other. The author feared that the steam would not be condensed by the quantity of water. But that was really a question of the amount of surface, and he did not think that it was at all likely the heater would fail on that account; the water that would pass through would condense all the steam that could be got into the heater, and he knew that the apparatus was very satisfactory in this respect. He had seen the report by Mr. D. K. Clark and Mr. Melrose concerning the heater, condenser, and evaporator combined on board one of the cable ships, the *John Pender*, he believed. The authors of that report spoke very positively of the action of the combined machines, and they spoke of the condensed vapour, and of the feed water and so on, and gave definite figures. Those figures had a very direct bearing on the present paper, and gave the sort of figures that were wanted. With regard to the Yaryan, there was some one in the room who could give particulars of that much talked of evaporator, and he thought that meeting would be very much indebted to that gentleman if he would do so. The author had suggested some limitations as to the way in which the evaporator should be used. It was not necessary that there should be any limitations in that respect. The secondary vapour, as it might be called, not only might be used for heating purposes, but really was used for heating purposes during its condensation in its passage to the hot well. In conclusion, he would express his sense of the value of the paper as a means of bringing the subject forward, but he believed that its value would be greatly increased if the author would include the further particulars which he had referred to.

Mr. Weir's Secretary, speaking on behalf of Mr. Weir, said that the feed heater had been treated so fully recently, not only in 'Engineering,' but in other publications, that it was scarcely necessary that he should refer particularly to a description of his feed heating appliances as fitted on board the s.s. *Normannia*, a description of which appeared in 'Engineering,' September 26, 1890; but he should be pleased to put upon the table one or two reprints of the description if it was considered desirable. Regarding the efficiency and economy derivable from the use of a feed heater, he might say, both from theoretical and practical results, that the saving of fuel by the use of

Weir's feed heater in compound engines, had been from four to five per cent., in the case of triple expansion six to seven per cent., and in the case of quadruple expansion engines from seven to seven and a half per cent.

Mr. Druitt Halpin said that he could not agree with Mr. Beaumont that the efficiency of a feed heater depended only upon the amount of surface. He had always looked upon the efficiency as depending upon the number of thermal units transmitted per hour per square foot of surface, per degree of difference of temperature that could be got through it. The stomach of the carnivora was very much more efficient per unit of area than the stomach of animals which eat vegetables, but the stomach of the latter was very much larger in proportion, than that of the former. With regard to Fig. 4 he quite agreed with the remark which had been made by one speaker that there was great difficulty in getting at the inner tubes if anything went wrong with them. He had used heaters like number 1, in which the arrangement was quite as good, and the whole apparatus could be taken to pieces without trouble. With regard to the grease question, he must say that he was so afraid of grease that he preferred throwing the water away altogether in order to make sure of avoiding grease.

Mr. Beaumont explained that he meant that, other things being equal, the heater which contained the larger amount of surface would, up to a certain limit, condense the greater quantity of steam per pound of cooling water used.

Mr. Chapman, upon being invited to speak, said that the only heater of which he had had experience was Kirkaldy's. He had come to ascertain whether he ought to change his views on the subject of heaters, but he had not heard any reason for doing so. As had been said by previous speakers, the paper had given no figures to enable one to judge of the relative merits of the heaters.

Mr. Godwin said that with regard to the question of where the steam should first meet the water in a condenser, he thought that it was best to follow the example of ordinary condensers which was to let the entering or hot steam meet the issuing or hot water, so that during the whole process there would be the greatest possible difference between the substance which was giving out the heat and the substance which was absorbing it. He thought that the best plan to arrive at the amount of economy to be gained by the use of a water heater would be to investigate it diagramatically, showing the temperature of steam at different pressures, the temperature of boiling water at same pressures, and the line of temperature of available feed water.

The Speaker drew the diagram on the block board and explained it, and showed that, using steam at 90 lb. pressure above atmosphere, the theoretical economy was raised to 24·7 per cent. He thought that this method of showing the economy was better than taking an isolated case as given in the paper. The only other point which he cared to speak about was with reference to the condenser shown on Fig. 6. He could not see that the water would come out as a spray on the leaving side of the bottom tubes, for even allowing for the slight increase of pressure on the incoming side, the tubes would still remain full, and it was this water that got cooled by the inflowing circulating water. As the condensed steam in the upper tubes formed, it would drop into the lower ones, and these being full it would only be this quantity that formed the spray.

Captain Grenfell said that, as chairman of the Yaryan Company, he had been somewhat disappointed in hearing the Yaryan evaporator dismissed in the way that it had been. The main principle in which that evaporator differed from those which had preceded it was that it dealt with water in rapid motion as distinguished from water at rest, and it had attained some very important results from a scientific point of view. He was sorry that no diagram of it had been exhibited on the wall. Had he known in time he should have been very pleased to have prepared a diagram for the reader of the paper. The water was within a tube and the steam was without, and an essential feature of the evaporator was, that there was not so much a jet injection as that there was a very small quantity of water present in the evaporator at any given moment. This was illustrated by the fact that in the evaporator, which turned out thirty tons of pure distilled water per day of twenty-four hours, there was never at any given moment more than about 18 or 20 pounds of water present. That small quantity of water became pulverised, so to speak, as it passed into the machine, and passed backwards and forwards with very great rapidity. The result was very curious from a scientific point of view. The effect of evaporating, or even heating, salt water was an almost immediate precipitation of the sulphate of lime, but in the Yaryan evaporator they did not get sulphate of lime, but what they got was the carbonate, and even then the quantity of carbonate was excessively small. Whether or not this result was due to the mechanical action of the rush of combined vapour and water through the machine he did not know, but he could state that principally there was little or no scale. As had been well said by Professor Lewis and others, the introduction of the evaporator was designed to remove the scale from boilers. It had done so at the expense of putting the scale in the evaporator. Therefore from a scientific

point of view he could not help looking upon it as an important step in advance if an evaporator was formed which in itself had no scale. Without being able for the moment to give an exact explanation of why it was that the Yaryan evaporator had no scale, he would merely say that one evaporator which had been in use for 142 days continuous steaming, when opened up had only $\frac{1}{32}$nd of an inch of scale in it, and that was carbonate. He thought that that was an extraordinary result. He was not in the slightest degree wishing to detract from the merits of any other evaporator. From a scientific point of view it certainly seemed a step in advance to have both boiler and evaporator free from scale.

Mr. SCHÖNHEYDER asked the last speaker what became of the sulphate of lime in the salt water. It must go somewhere. Was it destroyed or annihilated?

CAPTAIN GRENFELL said that it was an exceedingly interesting point that the whole of the sulphate of lime was apparently pumped overboard with the brine. There was none of it at all in the evaporator. If any of the gentlemen present wished to see the machine he should be very happy to show it to them. But as a scientific fact, the machine to which he had alluded had been running a long time and the sulphate of lime had all disappeared.

Mr. FLANNERY asked how the sulphate of lime was got rid of.

CAPTAIN GRENFELL said that the water in the tubes was in process of evaporation. They took off from 60 or 70 to 80 or 90 per cent. of water. It was admitted in the shape of water. The remaining 20 or 30 per cent. contained all the salts, and was pumped away as brine. That represented practically what had been done in other classes of machines. Of course something must be done with the salt. It had to be got rid of and that was the mode in which it was done.

Mr. DRUITT HALPIN asked whether the last speaker could give them the number of thermal units transmitted per hour, per square foot of surface, per degree difference of temperature. Such particulars would be most useful.

CAPTAIN GRENFELL said that he could not supply this information off hand.

Mr. HOWARD WRIGHT said that he was not surprised that the first speaker could not understand the working of the machine shown in Diagram 6, for the diagram hardly represented the machine as it was constructed. The steam inlet branch was cast much nearer to the top than it was represented in the diagram, thus enabling a certain head of water to be kept on the right-hand side. There was sufficient surface in the right leg of the upper tubes to condense the steam, or about three-quarters of it. The tubes were of sufficient area to

allow the condensed steam water to fall down to the bottom, so that it was not drawn over the top, as a former speaker had suggested. The air-pump on the other side drew equally down the upper and lower tubes. It was rather misleading to say there was a spray. The water flowing from the lower tubes was more like a fountain. In one of these condensers, which had been working in the North of England, the temperature of the condensed steam water when it came out of the hot well was within five degrees of the circulating water. If the water had remained in the bottom all the time without moving, it could not have possibly reduced the condensed steam water to that temperature. In that case the vacuum was always between 27 and 28 inches. With regard to the utilisation of live steam for heating feed water, it was very difficult, on the face of it, to see where any economy came in. It was stated that the water was cleansed. The cleaning would be very small, and if an evaporator was used the water would need no cleaning, for it was absolutely clean to start with. There were some theories about water taking up heat better when it was hot than when it was cold, but the unscientific part of such theories was very apparent. One of the speakers had said that the amount of steam that could be condensed by a heater would depend upon the amount of surface. But it was impossible to put more than about 160° units of heat into the circulating water, even when a vacuum was not required, so that it depended more upon the quantity of water than the amount of surface. As to the efficiency of heating surface in different heaters with a given degree of difference of temperature, if steam was admitted at a given temperature on one side of a tube, and water on the other, it would be simply a question of the thickness of the tubes. It was said that there was a difference in cleaning out the bent tubes, but he had had some experience of the bent tubes, and they were cleaned out in a rather ingenious way. Through a hole in the bottom provided for this purpose was inserted a hose, the end being turned up at right-angles, with the boiler pressure upon it, and at the same time that steam was allowed to go through the tube, a jet of cold water was allowed to play upon the scale. The effect was to contract the scale and cause it to fly off. But if the scale was allowed to become an eighth of an inch in thickness, it was almost impossible to get it off in that way, but of course if such a thing was allowed to occur, it was the fault of the attendant. He did not know whether he was in order in stating that the Patent Heater Condenser Company were about to put up in Yorkshire the largest installation of the kind that had ever been put up in this country. The plant was for heating

50,000 gallons of water per hour, and there was a guaranteed economy of 20,000 tons of coal per year. The works were now consuming 47,000 tons of coal a year with thirty-five boilers. The boiler power was very much less than was required, and they had to use jets of steam under the boiler to force the firing. All the engines were of very good construction, using from two to three pounds of coal per indicated horse-power; the majority of the steam was condensed for vacuum in the ordinary way. There were some thousands of vats which were filled with cold water, and then boiled up with direct steam. The proposition was to alter all the engines from condensing to high pressure, to take the exhaust steam to heat the water, and to supply it to the vats at 212° It was proposed, under the new plan, to pass the feed water from the heater into an economiser, where it would be heated up to 250°. The water would also be passed through a coil in the washing vats, where boiling was required for any time. It would be readily seen that the whole of the steam which had been used in driving the engines would now be saved, because the waste heat which came from the engines would go into the washing water, and save the use of direct steam. The extra steam which it took to drive the engines, when made to work high pressure instead of condensing, went through the engines into the wash-houses, whereas in the other cases it went direct to the wash-houses, so that the economy was equal to what the engines were taking at the present time.

Mr. R. L. Newman said that the previous speaker seemed to be doubtful as to the possibility of obtaining any further economy by heating the feed-water, as he had remarked that a pound of water would absorb a certain amount of heat, and he did not see how it was possible to put any more into it, or something to that effect; and, again, had stated that they utilised the exhaust steam from their engine, by passing it through their washing machines on the way to the condenser. This last remark embodied the principle on which the "Weir Feed Heater" is constructed, viz., that after the steam has passed through some of the cylinders—say two in a triple-compound—it is advisable to save as much as possible of the latent heat from the condensing water, storing the same in the feed-water, and sacrificing a very small percentage of the total I.H.P. As an example, if a sufficient quantity of steam is taken from the low pressure receiver into the feed heater, and is there mixed up with and condensed by the feed-water, giving up to this latter its latent heat, and raising the temperature of the whole to that compatible with the pressure of steam used, say 15 lbs., which is equivalent to a temperature of 212°,

thereby effecting a saving of from 10 to 12 per cent. of the total heat of evaporation, according to the temperature of the hot well; bearing in mind, however, that, owing to the steam having done no work in the low-pressure cylinder, it would naturally follow that the I.H.P. developed by this cylinder would be somewhat reduced. This loss would amount to about 4 per cent. of the total power developed. Therefore, by taking the gain due to the application of the heater as 11 per cent., and the loss of power as 4 per cent., it would leave 7 per cent. on the credit side due to the use of the heater. In view of the probability that the system of induced draught will be adopted in Her Majesty's service, and that the funnel temperature under this system becomes of slight importance, he would suggest to Mr. Weir that he should extend the operation of his heating system by utilising the waste gases to raise the temperature of the feed-water on its passage from the pumps to the boiler, to that of the water in the boiler, so that the only work the boiler would then have to do would be to supply the latent heat of evaporation.

Mr. Griffith, in replying to the discussion, said that he had, first of all, to thank the various speakers for what they had said about his paper. The remarks which had been made had greatly encouraged him. He thought that there was only one gentleman who required a direct answer from him, and that was Mr. Beaumont. That gentleman had referred to several weak points in the paper. He (the author) while admitting that such did exist, would offer a few remarks in explanation of those chiefly commented upon. Mr. Beaumont had said that the great variety of heaters shown by the diagrams proved that the statement made in the paper that little was being done by engineers generally in the way of feed heating was not true. He would read the sentence referred to, to show that Mr. Beaumont had mistaken his meaning. "It is a fact that in spite of the great number and variety of the systems at present before the public for its utilisation, comparatively little advantage is taken by engineers generally of the many applications to which it (exhaust steam) may be put." The use of exhaust steam for feed heating was treated first as being that part of the subject most generally adopted and the most thoroughly understood, but his contention was that the use of exhaust steam for condensation, and for what had been more recently adopted, viz., evaporation, and further for heating water for other purposes than feeding boilers, were subjects which had not received the attention they deserved. As they had seen from the statement of the representative of the

Patent Heater Condenser Company, very great things could be done by using the exhaust steam for other purposes than merely heating the feed water. He had shown that it was possible to apply it for heating large quantities of water for manufacturing purposes with very economical results. With regard to the lack of figures in his paper, to which several speakers had referred, he must confess that such a lack existed, and he would endeavour to give a reason for it. He could have gone to the various manufacturers and got particulars of the performances of their respective heaters, but such statements were he thought better given by the manufacturers themselves, if given at all. They would in any case be very difficult to compare one with another, and therefore would be of doubtful value, and he had hoped that, in the course of the discussion, gentlemen representing the manufacturers of the different apparatus described would have supplied the meeting with any figures that might be required, and have answered any questions which might have arisen in the minds of the gentlemen present. He must acknowledge that the value of his paper would have been greater had it contained numerical results of a reliable nature, and if he read a second paper on the subject, he would endeavour to make up for this defect. He felt most grateful to Mr. Beaumont for his advice and remarks upon the point. With regard to the areas of the tubes, Mr. Beaumont pointed out that none were given in connection with any of the heaters. Every maker of heaters made the apparatus of various dimensions according to the circumstances for which they were required, and of course the makers if consulted would recommend the sizes suitable for different purposes. There was, however, a general practice among makers, of publishing lists of their heaters with the sizes given in very obscure figures such as in nominal horse power, &c., and it was difficult for engineers generally to understand what these figures represented. Consequently it was very difficult to say what duty any given heater would perform under any given conditions, and even the manufacturers themselves, if consulted as to the size of heater suitable for any particular case, would recommend different sizes. It would, therefore, have been impossible for him to have selected any arbitrary dimensions for the purpose of comparison, seeing that the conditions under which the heaters worked and the statements of the manufacturers with regard to their respective performances would vary very much in themselves. He had hoped that, in the course of the discussion, some further attention might have been called to the principle upon which Mr. Weir's heater worked. That

would probably have been interesting and instructive to the members of the Society; but as that subject had been passed over, perhaps some communication might be obtained from Mr. Weir with regard to the action of his heater and evaporator. He believed that it was a subject in which many engineers would be interested, and he had no doubt that, if any gentlemen wished to know more about the matter, they could obtain every information from Mr. Weir himself.

Fig. 7.

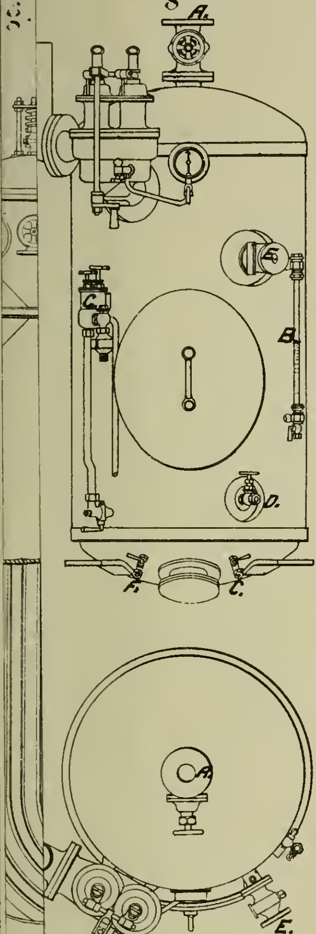
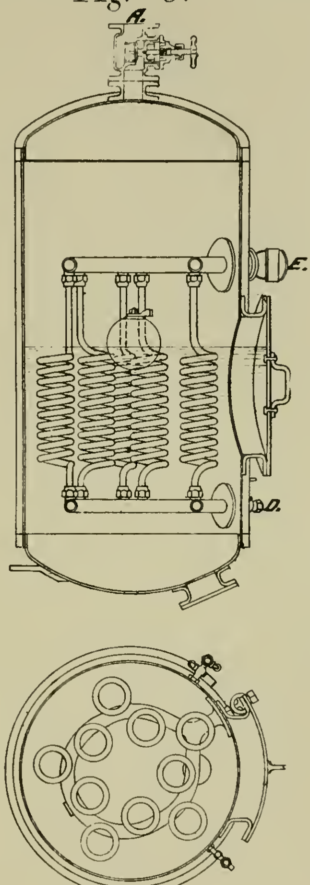
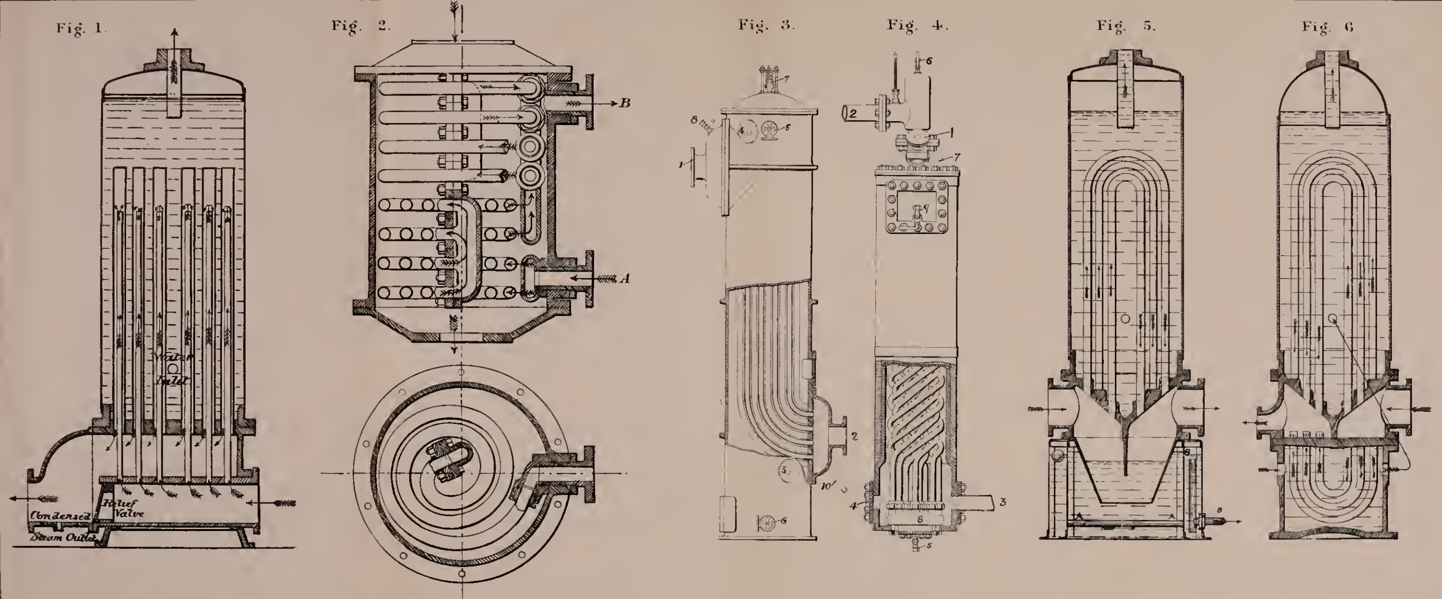


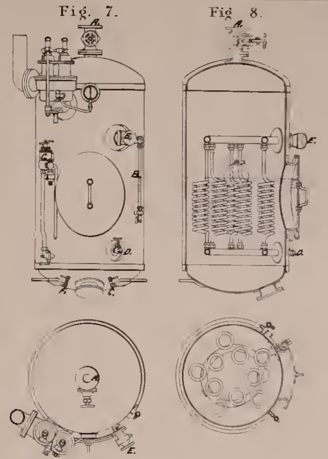
Fig. 8.



"COMPACTUM" EVAPORATOR.

. VAPOR PIPE LEADING TO MAIN CONDENSER OR WHERE REQUIRED.
. GAUGE GLASS.
DRAIN COCK, CONNECTED EITHER TO PUMP OR TO PIPE RUN INTO BILGE OR DRAIN.
. CONDENSED STEAM OUTLET FROM EVAPORATOR COILS CONNECTED TO EITHER FEED TANK OR MAIN HOTWELL, OR CONDENSER.
. STEAM INLET TO EVAPORATOR COILS, EITHER FROM MAIN OR AUXILIARY BOILERS, OR EXHAUSTS FROM AUXILIARY ENGINES.
BRINE COCK, CONNECTED TO PUMP.
FEED AND OVERFLOW VALVE, CONNECTED EITHER TO MAIN DISCHARGE PIPE, SEA, OR TO A PUMP FOR FEEDING PURPOSES.





"COMPACTUM" EVAPORATOR

A VAPOR PIPE LEADING TO MAIN CONDENSER OR WHERE REQUIRED
B GAUGE GLASS
C DRAIN COCK CONNECTED EITHER TO PUMP OR TO PIPE RUN INTO BILGE OR DRAIN
D CONDENSED STEAM OUTLET FROM EVAPORATOR COILS CONNECTED TO EITHER FEED TANK OR MAIN HOTWELL, OR CONDENSER
E STEAM INLET TO EVAPORATOR COILS, EITHER FROM MAIN OR AUXILIARY BOILERS, OR EXHAUSTS FROM AUXILIARY ENGINES
F BRINE COCK, CONNECTED TO PUMP
G FEED AND OVERFLOW VALVE, CONNECTED EITHER TO MAIN DISCHARGE PIPE SEA, OR TO A PUMP FOR FEEDING PURPOSES

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13. Fig. 14.

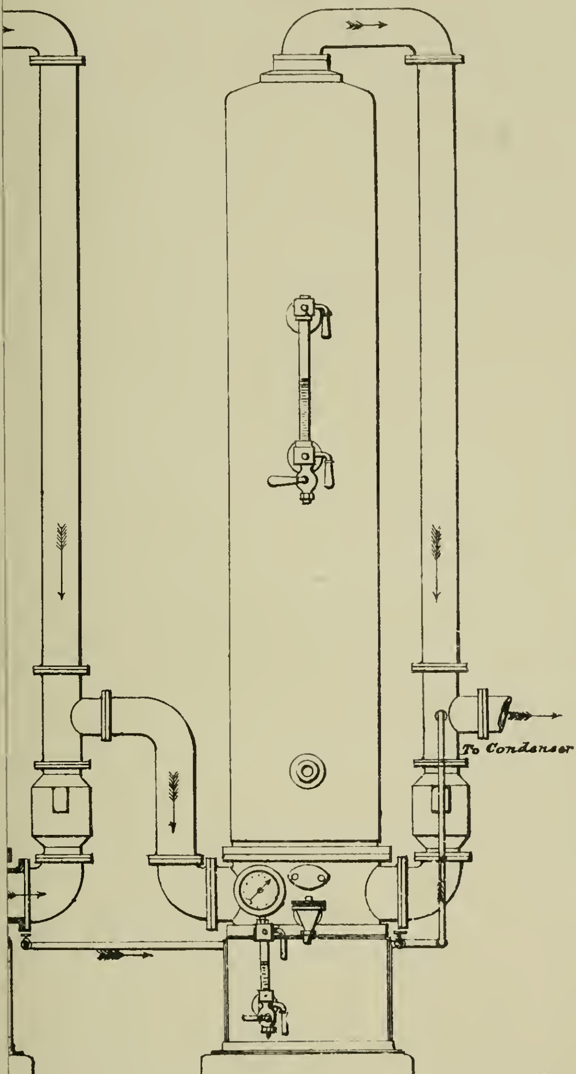

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Fig. 9.

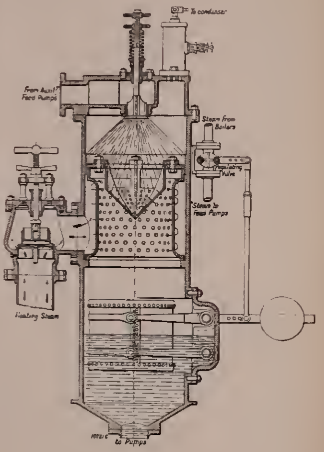

Fig 10

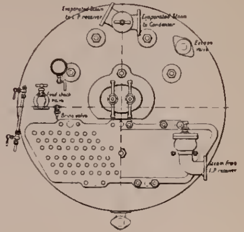

Fig. 11.

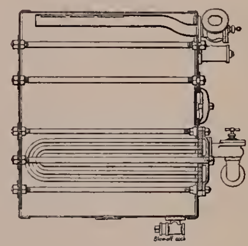

Fig. 12.

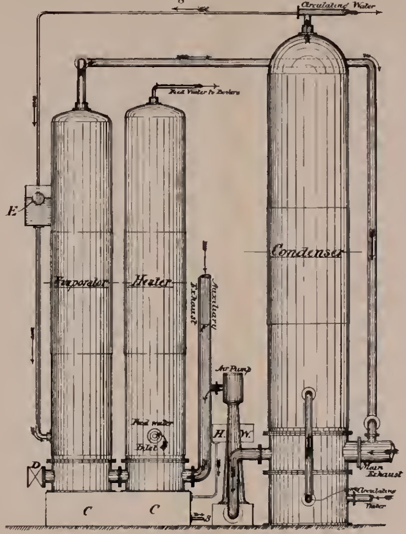

Fig 13.

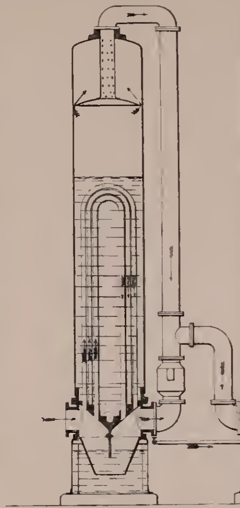

Fig 14.

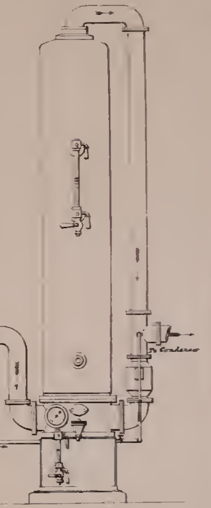

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Plate 3.

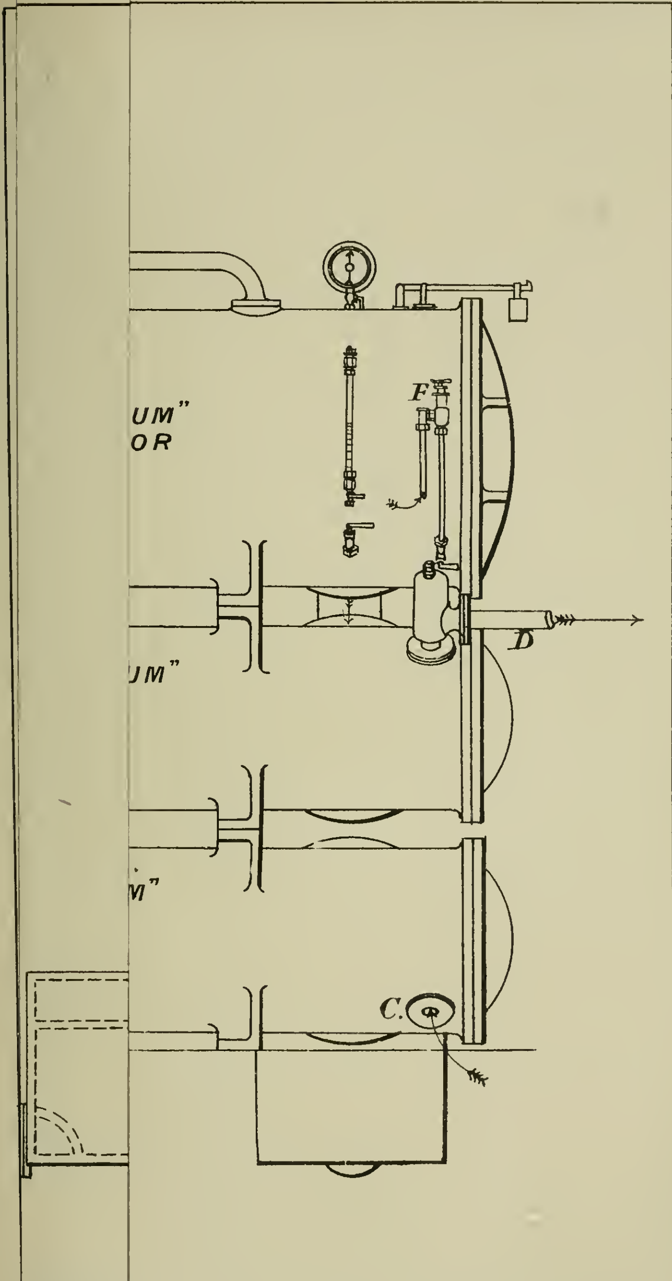

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Fig. 15.

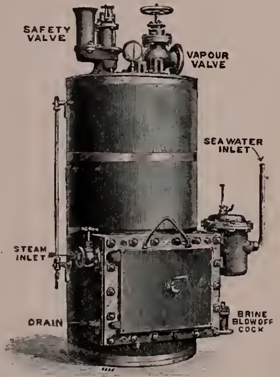

Fig. 16.

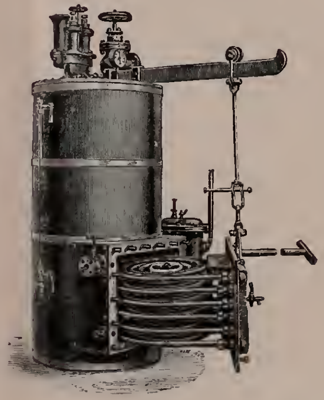

Fig. 17.

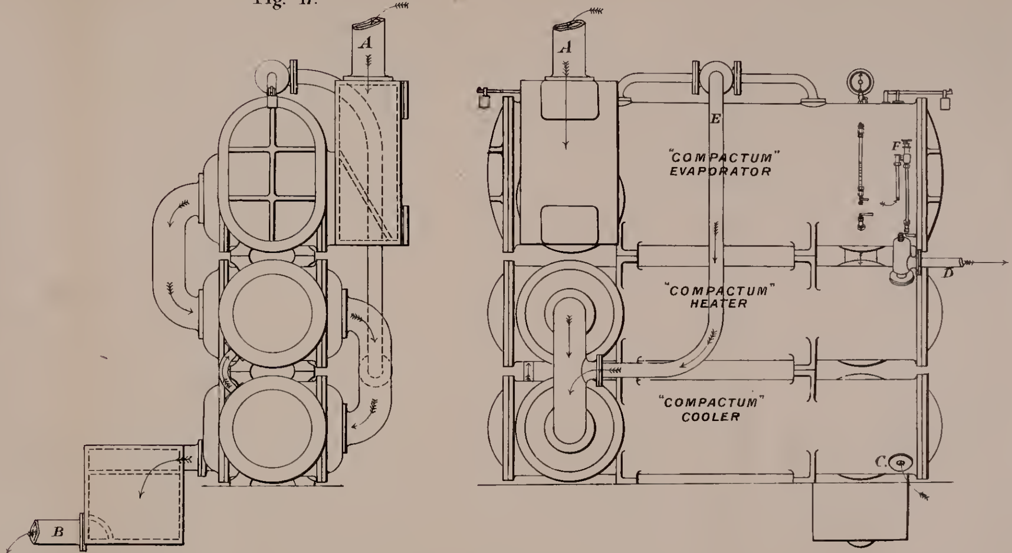

Plate 4.

3.

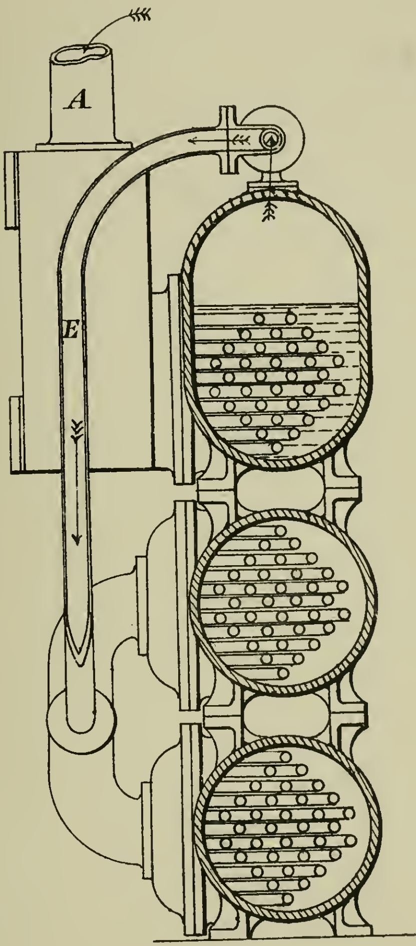

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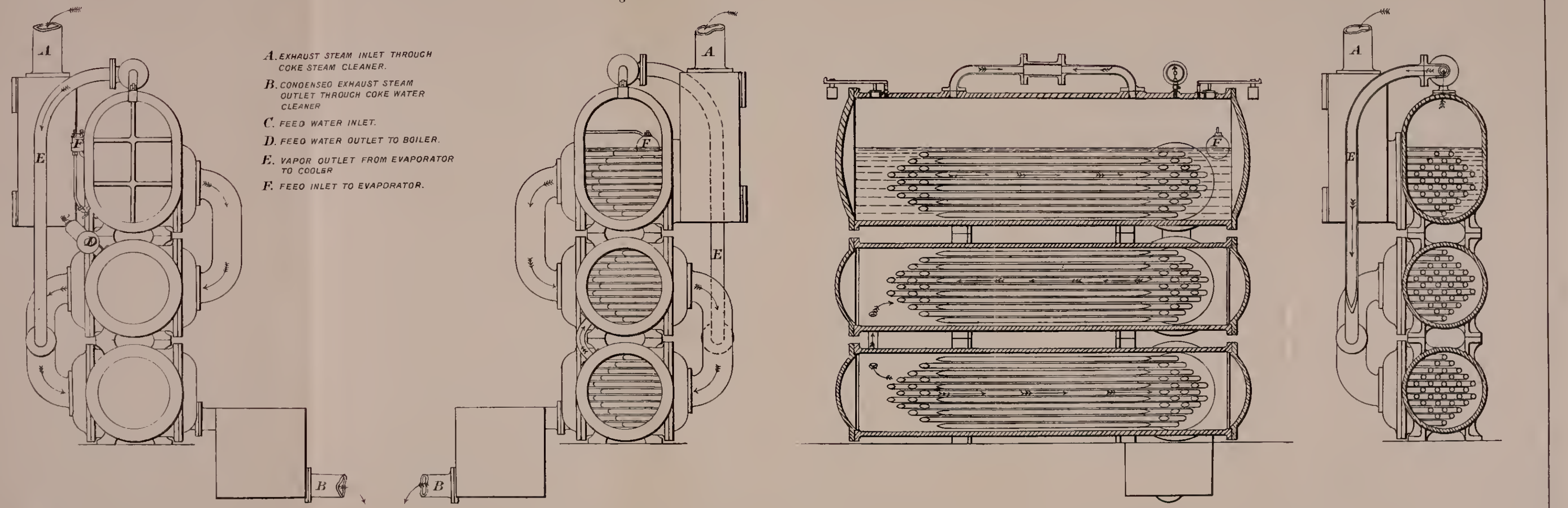
Fig. 18.



E & F N Spon, London & New York

December 1*st,* 1890.

HENRY ADAMS, President, in the Chair.

ON SHIP CAISSONS FOR DOCK BASINS AND DRY DOCKS.

By John Joseph Frederick Andrews.

The subject of ship caissons for dock basins and dry docks is one of great interest. The author, by his somewhat lengthened experience of them, is enabled to advance the following remarks thereon, and trusts that the members of this Society may deem them of sufficient value to find a place in their 'Proceedings.'

The author has sought for some standard authority which might assist him by indicating the course that should be taken in the preparation of a paper of this description, but has not been fortunate in finding anything that would serve as a basis on which to work; he must therefore rely upon the kind indulgence of the meeting with regard to the form in which the results of his observation are introduced.

The treatment of this subject will be as follows:—Firstly, a general review of the kind and description of ship caissons generally in use for dock basins and dry docks; secondly, general principles of construction; thirdly, general method of working; and lastly, a short description of the methods and details of construction as generally carried out.

In the caissons used for dock basins and dry docks of the present day, as compared with those of some twenty-five or thirty years ago, there have been very great changes in the principles of design and construction, in their size and dimensions, method of working, &c., from the early caissons as used at the Royal and other dockyards to the caissons at present in use; from the caisson closing an entrance of say 50 or 60 feet and with a depth of 25 or 26 feet, to caissons closing entrances of 94 and 95 feet opening, with a depth from sill to coping of 40 to 45 feet, and with water over the sill or invert of the entrance of 36 or 38 feet, such as are now in use. Further

existing examples of the great changes that have taken place in caisson construction may be seen by comparing the small caissons, having openings under 50 feet, for the entrances of the outer basins and docks of the older portions of the dock-yards at Woolwich, Sheerness, Chatham, and other places, with those of the larger and greater dimensions now in use at the extension portions of H.M. dockyards at Chatham, Portsmouth, and elsewhere, closing entrances of nearly 100 feet opening, and where also the alterations and improvements in design, type, general construction, and working can be compared.

The elements and principles of design depend very much upon circumstances, such as locality and requirements in working; but the author will endeavour to convey to the meeting, and place upon the records of the Society, such information as the result of his experience in the designing, detail, practical construction, and working, will permit, as carried out at the works of Messrs. Westwood Baillie and Company, with whom he has had the opportunity of undertaking this class of work. In considering the relative advantages of the different forms of caissons, consideration should be given to the purposes and conditions under which they will be used, such as depth of caisson, draft of water at which the caisson is to float, height of water for caisson to float out of groove, and all other particulars and requirements bearing upon the question.

In the present short paper it is intended to place before the meeting six various types of caissons, considering each respectively, as to form, construction, design, stability, flotation, and method of working. These types are illustrated in figures of the diagram as follow, viz. :—

Fig. 1. Caisson flotation with bottom buoyancy, sinking by water admitted to the bottom.

Fig. 2. Caisson flotation with bottom buoyancy with one watertight deck, forming an air chamber below the watertight deck; sinking by water admitted or run into a top water tank.

Fig. 3. Caisson flotation with air chamber formed by two watertight decks, water filling the lower portion below the lower watertight deck; sinking by means of water admitted or run into a top water tank.

Fig. 4. Caisson flotation with bottom buoyancy, as Fig. 1, but in addition having a central air chamber, as in Fig. 2, and sinking, if floating with bottom buoyancy, by water admitted to the bottom, or if floating with air chamber, by water admitted or run into a top water tank.

Fig. 5. Caisson flotation by central air chamber with two watertight decks, as in Fig. 3, and with a lower water tank;

sinking by the admission of water to the lower water tank, and water admitted or run into a top water tank.

Fig. 6. Caisson flotation with air chamber divisions along the sides, with one top watertight deck, water in the lower portion below the watertight deck; sinking by admission of water into the side divisions, or into the top water tank.

Fig. 1 represents the form of one of the simplest and earliest kinds of ship caissons floating with entire bottom buoyancy, and having ballast in the bottom to adjust flotation and give stability and steadiness at the particular draught of water the caisson is intended to be worked. This caisson is sunk into place by the admission of water to the bottom, the water so admitted being afterwards run into the dock or pumped overboard. It having been relieved of this water, the caisson is ready for lifting out of place, and for floating out of entrance as the tide previously admitted to the dock reaches the requisite height for giving buoyancy to the caisson. The caisson in this case would require the common centre of gravity of all the weights (i. e. centre of gravity of hull, of ballast, &c.) at some safe distance below the metacentre, when floating at the required draft, the requisite distance between the centres or the metacentre height being determined by the locality, and the depth considered necessary for safe working.

This kind of caisson may be seen at some of the smaller docks, as at Woolwich, Sheerness, and Chatham, and where the depth of opening is not great nor the rise of tide high. But for modern requirements and for greater openings and depths, some other varieties (see Figs. 3 and 5) are of more general use.

Before proceeding further with the descriptions of the caissons, it may be of interest to members of the Society to mention and describe the different centres and measures that require to be considered in preparing and designing the caisson as regards its flotation and stability when built and placed in working order. Firstly, there is that most important centre, the centre of gravity of all the weights contained in the hull, and this centre again resolved into a common centre of gravity, including the amount of ballast required to ensure stability and safe working. Secondly, the buoyancy or flotation, and the centre of volume of the buoyancy or flotation; and thirdly, the position of the metacentre above the centre of buoyancy or flotation. The counterbalancing forces are the buoyancy or flotation acting upwards through the centre of its volume, and the caisson with everything in it acting downwards through its common centre of gravity.

If the centre of gravity of a caisson and and all its weight,

comes without the vertical line through the centre of buoyancy when shifted to the side inclined, the weights will be acting down on that side, and tending to overturn the caisson. But if the common centre of gravity of weight of the caisson, &c., comes within a vertical line through the shifted centre of buoyancy with the caisson inclined, then the buoyancy will be acting up on that side, and tending to return the caisson to her upright position. Upon the relative positions of these two centres with the caisson inclined will depend the result that will ensue upon the inclination. A vertical line drawn through the shifted centre of buoyancy with the caisson slightly inclined, continued to, and intersecting the axis of the caisson cross section is the position of the metacentre, above which the common centre of gravity of all the weights must not be, to ensure stability and the caisson floating upright. The foregoing remarks refer to a caisson floating with bottom buoyancy. With a caisson floating with an air chamber, the common centre of gravity of all the weights must be below the centre of buoyancy of the air chamber and all the parts immersed, to ensure stability and upright floating of the caisson. It is a matter of important consideration that the distance, under any condition of working, between these centres shall be sufficient to ensure stability in the initial state, upon being inclined, and when being sunk into place, or raised for floating, and is determined by the particular requirements and working of the caisson.

Fig. 2 illustrates a section of caisson constructed with an entire bottom air chamber and one watertight deck, the ballast necessary for stability being contained in the lower portion of the air chamber, which is made of a sufficient capacity and buoyancy to float the caisson with its ballast and all other weights. In this form of caisson it is necessary that the common centre of gravity of all the weights should be below the centre of buoyancy of bottom flotation or volume of air chamber, to ensure stability when floating at about the level of the watertight deck, and likewise to keep the caisson steady, and close to the masonry faces without tilting when sinking or raising. This kind of caisson becomes applicable when there is no very great depth or height of water over the sill or invert of dock or basin entrance, the object of the watertight deck being that with the caisson in place, the latter may be retained in its entrance by means of a top watertight tank of such a capacity as to contain a sufficient weight or quantity of water to keep the caisson down, and to overcome the buoyancy of material immersed as the water rises in the upper portion of the caisson. The water is allowed to flow into and out of the caisson, over the watertight deck (as the tide

flows and ebbs), through flood holes in the sides, or trunks and valves as may be considered suitable for the safe working of the caisson. Water is retained in the top tank, until it is required to lift the caisson, when a valve in the tank can be opened and the water run out, whereupon the caisson being freed from this weight will gently rise to the surface of the surrounding water, at whatever level it may be on each side of the caisson. The caisson being then drawn back with one stem entering the masonry groove, the other being clear of the masonry face, can be swung out of its place, leaving the entrance free for the passage of a vessel into or out of the dock or basin. This being accomplished, the caisson, still floating, can be swung back and the stems adjusted to the masonry grooves of the entrance and then sunk into place by opening a valve and admitting water to the bottom, or by filling the top water tank from yard service or supply by hose or other means, the excess buoyancy being destroyed by the increased weight consequent upon the admission of water to the bottom or tank. Water will then be required also in the top tank, to overcome surplus buoyancy and to keep the caisson down during the rise and fall of the tides till it is again required to be floated.

It is usual in this kind of caisson, floating with air chamber and watertight deck, to have a small margin or reserve of buoyancy at the top watertight deck above the flotation line of caisson, to give stability when floating into or out of place. The following description may be taken as explaining the principle of construction of a caisson of this kind, and also the general method of working. At a certain height from the bottom of the keel there is a watertight deck, forming with the lower portion of the caisson an air chamber of sufficient capacity and buoyancy to float the caisson and all its weights, with a sufficient quantity of ballast therein to steady it. Above the watertight deck, water is admitted through valves, flood holes, or other openings; so that when the caisson is aground, and the water rising on either or each side, there is no tendency for the rising tide to float it. To enable the caisson to be raised, a small tank is placed under the top deck, which is kept full of water when the caisson is aground, and emptied when it is desired to raise the caisson; the reduction in the total weight by the amount of water run out of the tank enables the caisson to rise and float clear of the groove or sill. The position of the watertight deck is arranged so that it is a few inches above the water level when the caisson is floating. The opening of a valve admitting water to the bottom or air chamber is a more ready and rapid mode of sinking, should it

for any purpose be required to sink more rapidly. The water so admitted to the bottom is run off into the deck or pumped overboard after the caisson is in place and aground, sufficient water having first been pumped or run into the top water tank to prevent the caisson rising and to retain it in place; care is required in this kind of caisson to have the common centre of gravity of all the weights sufficiently below the centre of buoyancy of flotation of the air chamber and material to ensure stability in case of the caisson canting when floating, and to keep it steady when sinking by the admission of water to the top water tank, if sinking by this means. Another advantage possessed by the top water tank arrangement, in addition to that previously described, is that the caisson may be sunk and raised at short intervals, if required, by simply filling or emptying the top tank.

Fig. 3 illustrates a caisson with a central air chamber, formed by two watertight decks, at such a distance from each other as to form a buoyancy chamber of sufficient capacity to float the caisson, ballast, and all other weights. The portion below the lower watertight deck is open to the water, and has ballast in this space of sufficient quantity to ensure the caisson floating upright on the water, and to prevent overturning. In this kind of caisson it is requisite to have the common centre of gravity of weight below the centre of buoyancy of the air chamber, material, ballast, and all other parts immersed, so as to ensure a safe margin for working when sinking and raising; the method of sinking and raising is similar to that just described, except that the sinking may always be effected by the admission of water into the top tank. This kind of caisson is generally adopted for an inner dock or basin where there is a great depth of water over sill, and the caisson deep from sill to coping, with a good draught for flotation line or position of upper watertight deck. The centre of buoyancy of the air chamber being proportionately high, a correspondingly diminished amount of ballast is required, sufficient only to keep the caisson steady when sinking or raising. Several very large caissons of this type have been built by Messrs. Westwood, Baillie and Co., for dry docks and basins for the extension works at H.M.'s dockyards at Chatham and Portsmouth, and having openings of 94 feet and depth from sill to coping of 40 and 41 feet. The ballast required and used in these caissons for steadying and stability is of pig iron or "Seely's pigs," which seem to be admirably adapted to the purpose. These caissons are worked by means of a top water tank, as described in that illustrated by Fig. 2, water being admitted or run into the tank by means of a hose from the yard

service supply or water main. Water is freely admitted to the lower and upper portions of the caisson by means of flood holes through the sides, trunks through the air chamber, and by other means, and these being so arranged that water cannot flow through the caisson from the inner basin or lock into the dock. The method of working is performed in a similar manner to that described for Fig. 2, and the sinking and raising effected by admitting or running off water from the top water tank.

Fig. 4 illustrates a caisson having two different methods or combinations of flotation and working—viz., one with entire bottom buoyancy as in Fig. 1, and the other by the system of air chamber as in Fig. 3. Each system requires different treatment in the method and principles of construction, the one with the bottom buoyancy and flotation with stability by metacentre above the centre of gravity of all the weights for flotation at a very light draft of water; the other by an intermediate air chamber for floating at a higher or deeper draught. The requirements for this caisson being that it should be floated at a very light draught, an unusually broad beam at the flotation line with bottom buoyancy, was considered requisite to ensure stability. As the air chamber is placed at about mid depth of the caisson, the lower portion containing the ballast (and water when working with air chamber) the condition in the design as regards ballast is that when working with bottom buoyancy it should be sufficient to ensure stability, and also with the ballast immersed, when working with air chamber. The sinking and raising under the different conditions of working had also to be considered, that is to say, when working with bottom buoyancy, and when working with air chamber, the means of sinking being different for each method of working; for instance, when working with bottom buoyancy the water has to be admitted to the lower portion of the caisson when it is required to be sunk, and when working with the air chamber the sinking may be effected by filling the top tank, as previously described in the instances illustrated by Figs. 2 and 3. The water is retained in the top water tank, with the caisson aground, till it is required to again float the caisson. The ballast used is common or ordinary clinker set solid in the bottom with cement. Bulkheads are fitted above the top air chamber deck to prevent a flow of water to either end, which would tend to tilt or up-end the caisson when being sunk into place. Watertight trunks are worked through between the air chamber decks and top deck, and through the air chamber, for access to the different divisions and portions of the caisson.

The admission of water for sinking is effected by means of valves to the lower portion from the sea side of the caisson, and

by water from yard hose or service supply to the top water tank for filling same. This caisson has been made for closing an entrance of 70 feet opening, with a depth from sill to coping of 29 feet, and can be floated out with a draught of only 13 feet 6 inches, by having every chamber clear of water, thus allowing it to be worked with only 14 feet of water over the sill of the dock, which is the height of high water at the lowest neap tides. In the case of a high spring tide and a strong wind, the caisson can be floated at the deep draught of 17 feet 6 inches with the air chamber, by having the lower compartments full of water, thus giving very great stability and stiffness to the caisson. A caisson of this description was designed and built by Messrs. Westwood, Baillie and Co., for the London and North-Western Railway Co., for their graving dock at Holyhead, and very successfully answered the purposes required.

Fig. 5 represents the section of a large class of caisson for H.M. dockyards, and is similar to that illustrated and described under Fig. 3, except that a large water tank is arranged in the bottom chamber or division of the caisson, under the lower air chamber deck, for rapidity and stability in sinking. The water is admitted through valves from the lower air chamber or from the exterior of the caisson. Water in the lower tank gives great stability in sinking, and the water so admitted may be run into the dock or pumped up, and discharged either into the top water tank or overboard. Bulkheads are fitted in these caissons above the top water-tight deck, and communication is made with the different compartments and divisions of the caisson by means of trunks, &c., as described for the previous caisson.

Fig. 6 illustrates the section of a caisson with air chamber divisions along the sides, a top water-tight deck over, and water filling the lower portions as ballast, the capacity and buoyancy of the side chambers being sufficient to float the caisson and all her weights. The sinking is effected by admitting water into the side chambers to destroy the buoyancy. When the caisson is in its entrance and aground, the water so admitted may be run into the dock, or pumped up into the top water tank or overboard, as in the other caissons. The advantages of this form of caisson are, that the caisson may be floated and worked at any different or variable draught of water by running water into the side air chamber compartments, water being retained in the bottom chamber as ballast, thus enabling the caisson to be lifted and floated out of place at any state of tide, and by retaining water, in one side compartment or the other, the caisson can be heeled over for examination, cleaning, painting, or repair, without the necessity of docking or the removal of ballast, only a small quantity of ballast being required to

effect trim in a fore and aft direction, and to steady caisson and keep the stems fair to masonry when sinking or rising.

Having described the principles of construction, method of working, &c., of the various caissons, some more general description, apart from principle and working, may prove of interest to the Society. In the first place, great strength is required in the caisson stems and keel. A caisson, when in its place and aground and with the height of tide on one side only, with the dock empty on the other side, will have a pressure on her side due to the length and depth of the surface exposed to the water; and this pressure is transmitted through the caisson to the stems and keel of the caisson. These parts are therefore made of sufficient strength to resist the pressure on the sides. The stress on the caisson itself is that due to the pressure of water over the length and breadth of the caisson. Sufficient material has therefore to be provided in the sides, stringers, and internal bracings to give stiffness and strength to the structure, and in the skin plating and frames to resist pressure. The stability of flotation with bottom buoyancy is gained by a sufficient distance between the point or height of the metacentre and the common centre of gravity of all the weights; and the provision of the amount of ballast required for this stability and for stiffness for safe working. The metacentre, in the case of the caisson floating with bottom buoyancy, is from 2 to 3 feet above the common centre of gravity of weight, and with those floating with air chamber of from 1 to 2 feet between the centre of buoyancy of the air chamber and of all the parts immersed, and the common centre of gravity of all the weights. In the ship form of caisson, the position of the metacentre M above the centre of buoyancy or volume of flotation may be approximately arrived at by squaring the breadth and dividing by the draught at which the caisson is floating, and multiplying the product by ·08, or, shortly, $M = \frac{B^2}{d} \times \cdot 08$. The centre of buoyancy of bottom flotation may be taken approximately at $\frac{4}{10}$ equal to ·4, or $\frac{45}{100}$ equal ·45 of the draught at which the caisson floats below the line or level of flotation. It is, however, in any case absolutely necessary that these positions or points should be known by a correct and close calculation after all details, particulars, form of caisson, &c., have been determined upon.

The ballast generally used consists either of pig iron, of concrete cement, or of stone, slag, or clinker set in cement. A certain quantity of loose pig may be required for adjusting trim and flotation, to render the caisson steady, and to prevent tilting or up-ending when raising, lowering, and floating caisson. Bulkheads are sometimes worked across the caisson, above the top

watertight deck of the air chamber, to prevent wash or flow of water to one end, and prevent the caisson tilting or up-ending, also to render the caisson steady when being sunk or raised. Water is admitted to the several compartments by means of open flood holes, tubes, trunks, or valves, fitted through the sides or decks. Pumps are fitted leading to the various compartments of the bottom and air chamber, and made to deliver overboard or into the top water tank. Various kinds of pumps are in use, but those having the buckets in the rising mains are generally used in Government practice. Locking flaps are usually provided at each end of the stems of caissons, fixed to the masonry, or by some other provision, to hold the caisson down in place and to prevent flotation in the event of the tide rising, and producing buoyancy by the immersion of parts, or again from tendency to lift by force or pressure on the sides. The upper or top deck is generally formed of a light platform or deck to form a roadway, and in some caissons for the transmission of locomotives, goods wagons, and ordinary railway traffic across the dock entrance. In this case the deck is required to be proportionately strong and well pillared and stayed. The keels and stems of caisson or abutment timbers are generally formed of oak or greenheart, firmly secured by cheese-headed or other form of bolts sunk in and dowelled over and set in marine glue. The keels and stems are generally worked double faced to the masonry, so as to fit tight against either side of the groove in the fleeting over of the caisson, or to enable the caisson to be turned round if desired. Sometimes only one face of masonry is formed as a stop, for the stem of the caisson to fit against; in this case the caisson can only be used with the pressure of water on one side, but by this means it can be more readily floated out of place, and without so much lift as that required for a caisson having its stems fitting a groove which is required to rise sufficiently high to be drawn back into the masonry groove to allow the keel to clear the sill, or masonry of the dock.

Another important point is the launching of large-sized caissons. Several, as previously described, constructed for H.M. dockyards, were 94 feet long and 42 feet high, and had to be launched sideways down the ways. The question of stability in these instances became a nice consideration, for at the end of the ways, when the caisson should be water borne, the depth of water was very limited, being only 16 or 18 feet at high water, the caisson towering about 42 feet above the blocks, and with the cradle and sliding ways some 50 feet above the ground. The distance to be travelled before reaching the water was from 100 to 200 feet, and made it a rather difficult undertaking. In

building these caissons for launching sideways to the water and not end on, four or more sliding ways were placed under the caisson, with cradles, dog shores, and jacks to each. It may here be mentioned that when launching these large caissons, only a foot of reserve or measure of stability was given between the metacentre and the common centre of gravity of weight of hull, ballast, &c., this result being attained by the use of a considerable quantity of pig-iron ballast.

Apart from completing and launching large ship caissons from the yard in which they were built, some for Chatham and Portsmouth dockyards were prepared in the contractors' works and erected in place; they were erected some distance above the sill groove or invert of the dock, or masonry face, so as to allow of sufficient room for access around the keels and stems, and to the bottom for the work. The caisson was lowered from this position into its place or groove by means of hydraulic presses by gradual descents and removal of the blocks, wedges, &c., on which it was built. The caissons that have come under the experience of the author, whether built whilst the masonry has been under progress and then launched and floated round, or built and lowered and placed in their grooves or entrances for the first time, have all had a good and perfect watertight fit with the masonry faces, and this so exact, that notwithstanding the very great pressure or head of water, there has been no leakage or even "weeping" at the stems.

An ingenious device, the invention many years ago of Mr. Robert Baillie, for taking the contour of masonry grooves and faces for the stems of caissons which, being under water, would be otherwise inaccessible, consists of a trammel, with wheels or counters, to be drawn around the groove. A pencil or scriber is placed at the top, and marks on a board the line traversed, this gives a rather distorted figure and irregular curve, which, upon being measured or reproduced on a floor, or traced, the process being reversed, gives the fair and exact contour of the original masonry face.

As illustrating certain peculiarities of caisson construction, instance may be made of a caisson designed many years ago by Mr. Kinipple and built by Messrs Westwood, Baillie and Co. for the Limekiln Dock, Limehouse. The shape on plan is that of two dock gates joined at the centre, and of the square form athwartships. Another recently constructed for the Barry Docks, designed by Messrs. J. Wolfe Barry and H. M. Brunel, consists of one side fitting perfectly flat and straight against the masonry, and the other side of the ship or curved shape. This kind of caisson necessarily involved some very careful consideration and calculation. A description of some square and

sliding caissons would be of interest to this Society, but would be of a different character for investigation, and would take up too much time to be included in the present paper.

Trusting that the foregoing matter, although of only a short and perhaps vague description, may be of interest and value as a contribution to the proceedings of the Society, the author hopes to supplement the present paper by additional matter at some future period, when other particulars may be advanced in a more comprehensive and intelligible form.

DISCUSSION.

The President said that the paper which they had heard that evening was one of some importance to engineers, because the number of caissons required was comparatively few, and their development had necessarily proceeded somewhat slowly. The author had confined his attention to one kind out of several, and rather to principles than to details. But in the further matter which he had offered to the Society, probably, the best type of caisson would be put before them, and the full details of that type given. He begged to propose a hearty vote of thanks to the author for what he had already done, by preparing the present paper and the diagrams accompanying it, and on this motion being put to the meeting it was passed unanimously. He then invited Mr. Creswick, of the Admiralty, to open the discussion.

Mr. J. Frost Creswick said that he had had considerable experience in the design and construction of caissons. Among the old records of the Admiralty he had found three drawings of one of the oldest forms of caissons. One of these drawings represented, he believed, the first ship caisson used at the royal dockyards, and certainly the first caisson that was ever made with an air chamber and tanks or cisterns. The little ship basin at Portsmouth, when that design was made in 1793, was called the Great Basin, and it was to close the entrance of this open tidal basin that the caisson was built. The first drawing showed a design for a floating dam, but Sir Samuel Bentham, who was then what might be called the Director of Works for the Admiralty, reconsidered the matter, and on this first drawing there was a pencil sketch, showing the birth of the ship caisson. Sir Samuel Bentham extended the floating dam sideways to get more displacement, and put a scaffolding on the hull to form an upper dam and to carry a roadway, thus avoiding the cost of a separate bridge. He then completed his idea, which was represented on the second drawing, showing

what he termed a floating dam, for it was not then called a caisson. A perspective view accompanied the second drawing when it was submitted to the Admiralty. The special feature of the caisson was that it could be floated out of its groove at any high tide without requiring to be pumped out. The flotation line of the air chamber, and of "the cisterns," as Sir Samuel Bentham called the tanks, was just above half tide level. There were six cisterns in the upper part of the watertight portion of the caisson, and when these were filled the caisson was sunk. When the caisson had to be lifted by the rising tide, the sluices were opened about the time of low water, and the water was allowed to run out from these cisterns. The sluices were then closed, and as the tide rose it lifted the caisson. The ship caisson at Portsmouth was certainly the first in which no pumping was required. The object of the top water tank in existing caissons is to enable them to sink the caisson in the same way as these cisterns did when refilled, but if they wanted to raise the caisson again after it was sunk, or unexpectedly before high water, after the tide had risen above the upper part of the tanks or cisterns, which would then be full of water, they used pumps to pump the water out. This was a very striking and original design; it was made in the year 1798, and the caisson was placed in its groove at the opening of the basin in January, 1801. It formed a roadway. Cisterns and valves were used for the first time, and pumps were only used as auxiliaries. The caisson could float out at any high water, and could be replaced in ten minutes. The cisterns were below the normal flotation line, and the water could be got into them quickly through the six large valves.

The next ship caisson that was made was designed by Rennie, and was placed in the entrance of the basin at Sheerness, where it was opened in 1823, just after his death. Through some extraordinary lapse, the designer seemed to have no knowledge of that particular caisson designed twenty years earlier by Sir Samuel Bentham, and his original idea was practically lost, and was not reproduced until about 1860. This first Sheerness caisson was of the type shown by Fig. 1, generally called a "sinker." It was a long step backwards, as the caisson could not be lifted without the use of pumps, and this was a very slow and expensive process. The first iron caissons in the Admiralty service were made in 1846, one for Malta and one for Portsmouth. The single watertight deck was introduced in 1850; two watertight decks and a tank were adopted in 1862, and the more modern type with the deep grooves and the chocks for keeping the caisson central

in its entrance, was introduced at Chatham in 1870. A great many of the older ship caissons, and some he was afraid now, were constructed just to fit the groove and go into place like a hatch or shutter. This made it exceedingly difficult for the caisson to rise and clear the groove; whereas, if a deep groove were made for each stem the caisson could be pushed back into one groove when about to rise, and then the other end could be easily swung out. Caissons were usually roughly classed as harbour caissons, basin caissons, dock caissons in a basin, dock caissons in a harbour, and what were called sinkers. The last type should only be used as a spare caisson in cases of emergency to fit up against a stop, such as Mr. Andrews had mentioned; for instance, there is a large sliding caisson closing the entrance from the harbour to a basin of 15 acres at Portsmouth Dockyard. It is 94 feet wide in the opening, and if by any means this caisson got jammed and the tide were sinking rapidly, there would be a series of very serious accidents to any large ironclads afloat in the basin. For this contingency a spare floating ship caisson is held in readiness. There was, likewise, one at Chatham in the 20-acre basin near the west river entrance which was closed by a ship caisson. In the present Admiralty practice they would not close a large basin with a ship caisson. They would use a sliding caisson because they would have more complete control over it, as the widest entrance can be closed by such a caisson in about five minutes. He (Mr. Creswick) next described a large ship caisson built for dock No. 3 at Devonport, (see Fig. 7), which was designed about 1880, and was completed and put into place in 1883. It was the most recent type which the Admiralty used, and he believed that it was the largest caisson in the world. The width at the coping was 94 feet, and the depth over the sill from the coping level was 43 feet. The result of those figures when multiplied together is taken to represent the nominal area of the entrance opening, the slope of the sides being neglected. They had two or three more caissons 94 feet long, but they were not so deep as the Devonport caisson. They also had one or two deeper, but they were not nearly so long. The Devonport caisson consisted of an air chamber similar to that of Fig. 4, with a bilge or water chamber below, open to the harbour through a series of flood-holes. Above the air chamber were three water chambers, that is to say, there were two transverse bulkheads so placed that the two end chambers were together made equal in capacity to the middle chamber. The large valves in the end chambers and the openings to the mid chamber were on opposite sides of the caisson, and were

open to the harbour or to the dock, as the case might be. The peculiarity of that caisson was not only its size but that for the first time there were employed large valves to shut the water out, or to keep it in, or to let it flow in and out of the two end chambers. This arrangement had given a great advantage in working the ship caissons, because by shutting the valves in the end upper chambers, they could control the displacement of the caisson at any level of the tide above low water neaps, which gave them the facility of floating the caisson as soon as ever it would clear the groove, and the power of so regulating its flotation that it did not rise any higher than was absolutely necessary for working it out of or into the dock entrance. All the other ship caissons had to rise until their fixed flotation line attained the tidal level, whatever that might be at the time. If they were to be used at high water spring tides they had to rise right up to those tides, exposing a large and unnecessary freeboard. They could imagine that when there was a gale or even half a gale blowing, it was very dangerous to move a caisson with such an exposed side. The openings and valves were generally too contracted, the water passed in or out very slowly, and when it had to run out of or into the whole of the space between the flotation line and high water spring tide, the lifting or sinking of the caisson was a tedious operation. With the Devonport caisson it did not matter what level the tide was above the half tide, as the caisson need only rise three feet to swing out of its groove. Another point to be mentioned was the stability of this caisson. Calculations had been made and the weights and buoyancy so adjusted that she would float stably with her top tank full of water, so that if she were lifted out of her groove by using the end valves and the water were left in the top tank, she could be swung out of the way with her surplus sinking weight all ready for use. That is to say, when she was put back into the dock entrance, she was swung into the groove with the top tank full and sunk in a few minutes. So stable was she with her top tank full of water and with the valves closed, that she had been floated out of the entrance easily at half tide, reversed end for end, and put in the groove the opposite way when half a gale was blowing, and boats did not venture to put off to the ships in the harbour. Her handiness was partly attributable to another detail which he did not think existed in many modern caissons. There were four small capstans on the quarters, so that the working gang had complete control over the caisson, and they could turn and twist it about as they liked. With regard to the depth of the grooves of the caisson, of course that assisted considerably in pushing out as

soon as the keel had risen out of the groove below. In these grooves at the upper part there were two adjusting chocks which kept her up to the centre and gave her an even overlap on the masonry. The locking flaps which Mr. Andrews spoke of were also very necessary. If by any chance the valve of the top tank leaked or some mischievous person opened it, the caisson would have a tendency to rise out of the groove. Such a thing might happen during the night, and, in fact, it had so happened on one or two occasions. The locking flaps on each side securely held the caisson down with a force equal to the weight of the water ballast which was in the top tank. Another improvement was to avoid having the flat wooden keel filling the bottom of the groove. It had happened that such a thing as a cannon ball had got into a groove, and consequently the caisson tipped up at one end. It was floated again and a diver was sent down to remove the obstruction. The timber keels now made were always lifted on an iron shoe 3 or 4 inches above the masonry so that there might be a space underneath. The groove should be cleaned from time to time with a sort of scoop or large scuttle let down on one side, worked across the groove and taken up the other side, and this more particularly if there were no diver at hand. Another advantage in this form of construction as regards the air and water chambers was that the caisson could be painted inside and out in every part with the exception of the foot which it stood on, without being docked or the dock being interfered with. By turning the caisson the upper chambers could be painted alternately, and then by letting water into the upper chambers and closing the valves they could drain off the bilge water. Of course there was an outer stop to the entrance, and by lifting the caisson against this outer stop, the granite groove in which it usually rested, or any part of the entrance could be got at for inspection, repair, or alteration. Another great advantage of the ship caisson was that in a very long dock they could have two or three grooves and so regulate the size of the dock and the amount of the pumping out, according to whether they had a long ship or a short ship in the dock.

Many persons asked why the Admiralty always employed caissons instead of gates. The last pair of gates which they had made were put up at Devonport in 1863, and they cost 37*s*. per square foot, the nominal area being ascertained by multiplying the width at the top by the depth over the sill. This cost did not include a bridge. Such a pair of gates would only hold up the water in one direction. The large caisson at Devonport, shown on a diagram attached, cost about

2*l*. a square foot of nominal opening. It was equivalent to a double pair of gates, and a bridge over which a 40-ton gun or boiler could be taken on two four-wheeled bogie trucks. Gates required a greater length of entrance, which had to be added to the cost of the dock per foot run, so that the total cost of the gates sometimes came up to two or three thousand pounds. The gates gave a greater leakage length both vertically and on the sill; and the sill, instead of being straight, was either segmental or angular. Besides this the masonry was more difficult to face where gates were employed, while there was no great difficulty in facing the caisson grooves. In the case of the caisson to which he had referred, the cost of 2*l*. a square foot was rather an economical price. The caisson, which had been built on the principle of Fig. 4, had cost 2*l*. 7*s*. 6*d*. a square foot. Two other large ship-caissons at Haulbowline had been made for a little under 2*l*. In comparing English prices with French prices he had found that a caisson at Havre had cost 2*l*. 2*s*. 6*d*. for the larger caissons, and about 2*l*. 12*s*. 6*d*. for the smaller ones. At Marseilles, where the water was almost tideless, the cost had been 1*l*. 13*s*. 8*d*. A caisson could not be constructed exactly according to one particular type, but it must be suited to the tides which it would have to meet, and to the circumstances under which it would be used. When those circumstances were known they could fix the position of the air chamber decks and the height of the flotation line, and complete the design in accordance with the special requirements of each particular case.

Mr. A. T. Walmisley said that there was no doubt that in these days of increased demand for water communication, and additional harbour accommodation, more and more attention would be given to this subject, and hence the paper would be a valuable addition to the Transactions of the Society. His experience had been limited chiefly to timber caissons, such as they had for a small basin at Dover, where floating timber caissons were used when they wanted to examine the gates. They were made of a rectangular shape, designed for an opening 65 feet wide by about 25 feet in depth. They were floated into position, and then fixed by an action somewhat similar to that in the model on the table. In the groove there was a pile acting vertically, which pressed down by the side of another vertical pile, and drove the caisson forward by a parallel link action in a horizontal direction, and so wedged in the caisson between the quay walls. He had had some experience of floating docks, with regard to which a very able paper had been read before the Society by the late Mr. Standfield, and appeared

in one of the volumes of the Transactions. He quite agreed with the remark that it was everything in a caisson to have it under complete control, and so to arrange the water-tight decks and the bulkheads that the caisson should at all times be manageable. Of course the more the labour of pumping could be reduced the better.

Mr. J. A. McConnochie observed that Mr. Creswick in his remarks had really anticipated anything he had to say. He was desirous, however, to remark on the importance of being able, by valves, to control the raising of a caisson, so that it should just clear the grooves, as otherwise the high freeboard would prove very inconvenient in manipulating the caisson, when there was much wind blowing. In the course of his practice he had used caissons of the types shown on Figs. 1 and 2, the conditions being favourable for these types; but having occasion recently to send a caisson to Bombay, for the Port Trust Dry Dock, he availed himself of the information and advice very courteously given him by General Smith and Mr. Creswick as to the latest Admiralty practice, and sent out a caisson similar to that at Haulbowline, as has been explained by Mr. Creswick. The facility with which this caisson is worked and controlled has given much satisfaction. He had occasion, about eighteen years ago, to design a caisson for the Marquis of Bute's Dry Dock at Cardiff (see Fig. 8), and as the tide there made the conditions somewhat unusual, inasmuch as the working water level varied about 16½ feet, and the caisson was also required to work and be stable at a light draught, he had the benefit of the advice of Sir E. J. Reed in determining the general principles of the caisson, which are shown on the accompanying diagram. The caisson is worked by water ballast, and the lower portion is divided into sixteen compartments, communicating with each other, but so as to prevent the caisson from taking a list. A displacement scale is provided so that the necessary quantity of water can be run off into the dry dock to suit the level of water at which it is to be floated, and no pumping is required. With regard to the question of the comparative merits of caissons and gates, so much depends on individual circumstances that he would rather defer his remarks till another occasion, when that question may be more fully before the Society, but, speaking generally, he is of opinion that caissons are not suitable for commercial *wet* docks in a tide way, where locking is constantly going on from low water to high water, as in the Thames. He should be glad if Mr. Creswick could tell them the comparative cost of the sliding caisson and the ship caisson, when the cost of the walls of

the camber required for the sliding caisson are taken into account.

Mr. Creswick said that he could not give the comparative cost, taking the camber walls into account; but, after all, the camber walls were not a very expensive item. As regarded the cost of the sliding caisson in comparison with gates, it must be noticed that there must be two pairs of gates, one in and one out, in order to answer the same purpose as a sliding caisson, and there must also be a bridge. The price of gates has been quoted at from 30*s.* to 40*s.* per foot super, and then the bridge would be extra. They could have a sliding caisson complete for four guineas per square foot of nominal opening. That price included the whole of the machinery for working the caisson, and the decking of the camber into which the caisson was hauled.

Mr. McConnochie said that what he meant was rather a comparison between the ship caisson and the sliding caisson, when the cost of the walls, &c., necessary for the camber of the latter were added.

Mr. Creswick said that they considered the sliding caisson to be a special machine altogether, more particularly for closing the entrance to a lock or basin in a tidal sea or river, and they would never think of putting a sliding caisson in a dock leading out of a closed basin. It would be a waste of money. They would no more do so than they would now put a ship caisson into a large basin entrance from a tidal river. When the river was ebbing and flowing very rapidly, the level in the basin was affected, and, in spite of large culverts, there was a great stream of water through the open entrance of a twenty or thirty acre basin, and it is very difficult to handle a ship caisson under such circumstances. They would never compare a ship caisson with a slider, although, in many places, it would answer the same purpose. The Admiralty had sixty caissons now in use. There were fifteen sliding caissons, and, of the floating caissons, thirty-seven were ship-shaped and eight were box-shaped.

Mr. P. W. Meik said that although there were places where a sliding caisson might be very useful, and might be a cheaper article, he believed that those cases must be very few. In the case of a graving dock the ordinary ship caisson answered all purposes. He imagined from Mr. Creswick's remarks that he was of the same opinion. In the case of a floating dock, a pair of gates were undoubtedly cheaper. There were very few cases in which it was necessary to consider the sliding caisson as answering the purpose of a double gate. Of course such

cases happened, but he had never had one within his experience. He thought that for ordinary dock work, gates, even with a bridge added, would be considerably cheaper.

Mr. Brereton remarked that as the caisson at the Barry docks had been referred to as possessing peculiarities of design, possibly some information respecting it might be of interest to the meeting. This caisson was designed to act as a stand-by to the lock gates, and also to fit the entrances to the future lock and graving dock, making in all six positions in which it might be used. It is half ship-shaped in section, having a flat front and a rounded back, and is 85 feet long, 48 feet 9 inches high, with 24 feet beam at the widest part. The displacement at the ordinary draft is about 777 tons, and at the light draft 710 tons. The greatest head of water to which the caisson is exposed is 45 feet, representing about 2000 tons pressure on the caisson. The weight of the hull and fittings is about 357 tons; there are 354 tons of iron ballast, and at the ordinary working trim 66 tons of water ballast. The caisson is provided with an air chamber, upper and lower water chambers, and upper and lower water tanks. In ordinary working the caisson is floated off its blocks by letting out water from the top tank, and is sunk into position by filling the lower tank with water, which is subsequently transferred by pumps into the upper tank. When the caisson is required to float at a lighter draft than the level of the top of the air chamber, the water is run out of the tanks and ejected from the lower water chamber, the caisson thus becoming a ship with metacentric stability.

Mr. J. Bernays said that he had thought of asking Mr. Andrews what was the object of the top tank, but the inquiry had become unnecessary, as Mr. Creswick had so clearly explained that it was simply for accelerating the work, and keeping the gates well in hand. The only caisson which he had designed was one with flat sides, or of box form, for a dock with an opening about 60 feet wide. It was made very narrow, only about four feet across, and in order to strengthen it, girders were put on outside horizontally. The stability on flotation was assisted by timbers secured at the top. This was made about thirty or thirty-two years ago. At that time details of caissons were not forthcoming, and he had to design a structure as best he could; it, however, answered very well. In order to be perfectly sure of its working, Sir William Fairbairn was called in to give his advice on the subject, and see that all the details had been made of sufficient strength, and Sir William seemed to find very little fault with it.

Mr. C. S. Meikin said that he was certainly of opinion that,

for ordinary dock purposes, sliding gates would come cheaper than caissons, if all that caissons required was taken into consideration. But the question was one which could only be settled by its being worked out.

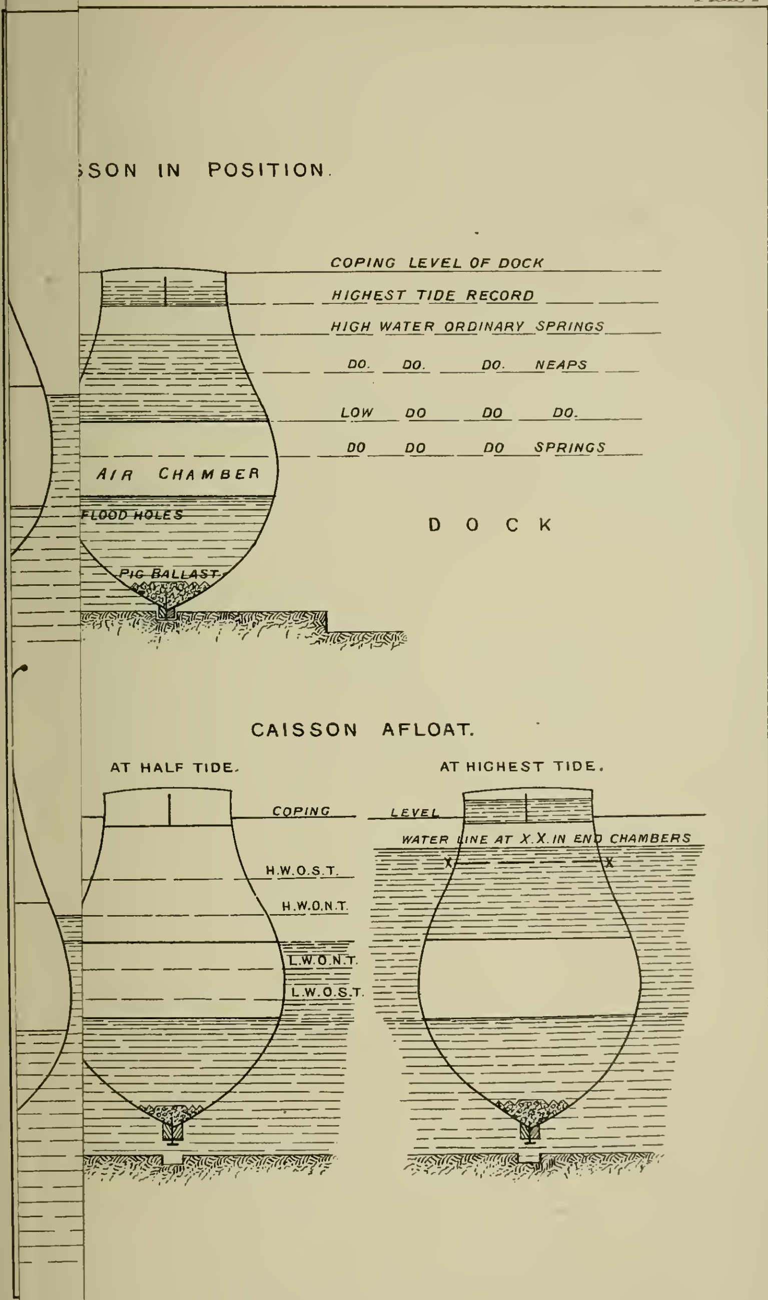
Mr. J. J. F. Andrews, in replying to the discussion, said that he was pleased that Mr. Creswick had brought them some illustrations of very early designs in caisson practice. They were certainly very striking and original, and seemed, in principles and methods of working, to be almost in advance of some existing caissons. Mr. Creswick was a better authority on caissons, and knew more than he (Mr. Andrews) did about them. His explanation of the caisson for Devonport, of recent construction, seemed to bring out many very advanced points, both in the mode of construction and in the method of working. The working of caissons with capstans was certainly novel. It was a very good thing to be able to work a caisson in and out, or to direct and manœuvre it as they felt disposed. Mr. Creswick's system of using water for ballasting, and the general arrangements of the caissons seemed very complete. He (Mr. Andrews) forgot to mention in his paper, in speaking of the working of caissons, the method of drawing the caissons back into the groove, the principle of having a chock to go behind the stems. The groove was made considerably larger than the stems at the back of it, so that the chock might be slipped down behind the stems. For lowering the caisson into its place, the chocks regulated and guided it; after the caisson was lifted the chock was thrown out. Thereby freedom was obtained at the back for the caisson to be drawn back into its groove and the caisson was then ready to be swung out at the other end, clear of the entrances. At some future time he hoped to be able to say more on various points which had been referred to in his paper. The object of the top tank, to which Mr. Bernays referred, was that the caisson might be retained in its place till the exact moment arrived for lifting it. The water in the tank kept the caisson down. There was a buoyancy which the water in the top tank overcame. Immediately it is desired to lift the caisson, a valve may be opened in the bottom of the tank; the water in the tank then runs out, and the caisson gradually rises. The system was very simple, and a caisson might be taken out and put back again by simply filling and emptying the top tank. Mr. Creswick had given the time at which that principle was introduced as 1841.

Mr. Creswick said that it was 1862. He was only speaking of Admiralty practice.

Mr. Andrews said that he believed that the principle was

used many years ago in a caisson built for the East and West India Docks Company.

The Author concluded his reply by thanking the President and members of the Society and others present for their vote of thanks, and for the kind consideration and attention given him in the reading of his paper.


SSON IN POSITION.
COPING LEVEL OF DOCK
HIGHEST TIDE RECORD
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FLOOD HOLES
PIG BALLAST
D O C K
CAISSON AFLOAT.
AT HALF TIDE.
AT HIGHEST TIDE.
COPING LEVEL
WATER LINE AT X.X. IN END CHAMBERS
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Fig. 1.

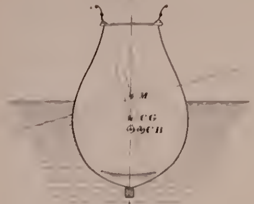

Fig. 2.

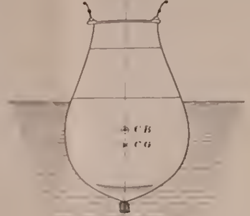

Fig. 3.

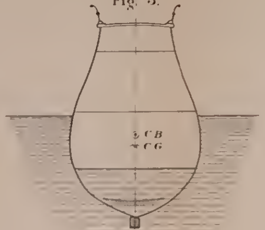

Fig. 4.

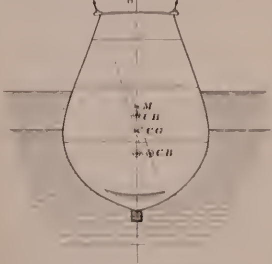

Fig. 5.

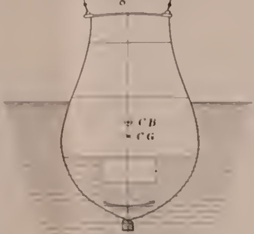

Fig. 6.

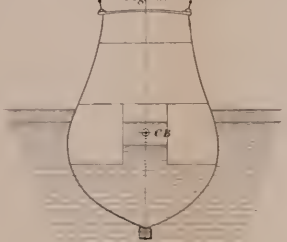

Fig. 7.

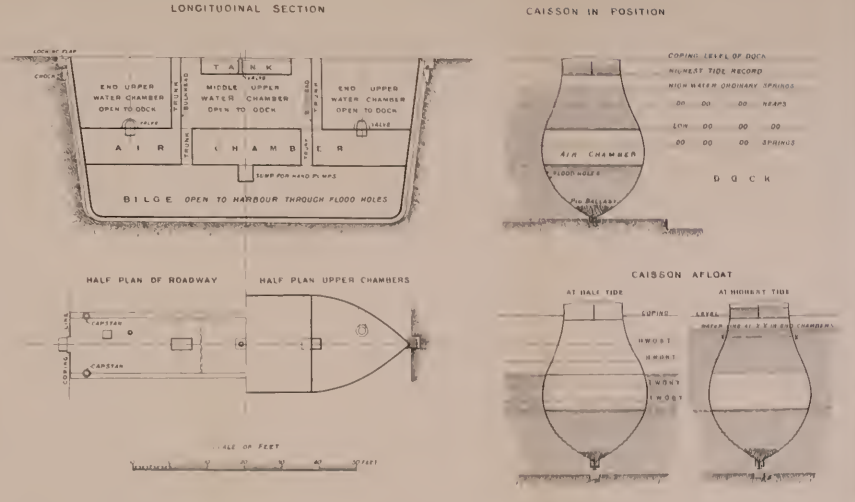

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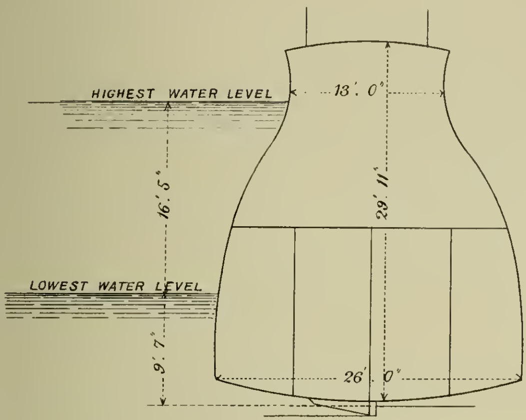
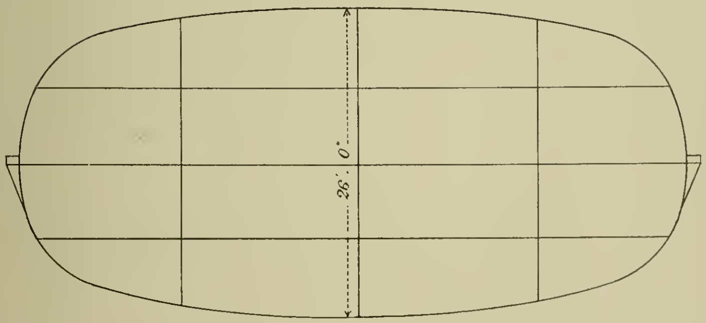
Fig. 8.



MIDSHIP SECTION.



PLAN THRO' COMPARTMENTS.

E & F. N. Spon, London & New York.

Obituary.

Thomas Dowrie (*Foreign Member*) died on the 3rd of January, at the age of 60. A native of Ayr, he was apprenticed to Messrs. Denny, of Dumbarton, and afterwards served as an engineer in the services of the British India and of the P. & O. companies. He then devoted himself principally to the question of the production of artificial ice, patenting some processes in connection therewith, and was engaged in its manufacture at Tamarang, in Java, for about seven years, and subsequently in Port Said, where he died.

John Standfield, M. Inst. C.E., senior partner in the firm of Clark and Standfield, of Westminster, and of Greys, Essex (*Member*), lost his life off Margate on 2nd March, during the foundering of part of the steamship *Ville de Calais.*

This vessel was built for the transport of petroleum in bulk, and it was on the completion of her first voyage, while lying in Calais Harbour, that on the 17th October, 1888, the memorable explosion occurred, whereby several lives were lost and the whole of the midship portion of the vessel blown completely out, leaving only the stem and stern portions intact. The wreck having been put up to auction was bought by Mr. Standfield's firm, and considering its condition he decided to cut it into three portions, the stern with the boilers and engines forming one, the bow another, and the remains of the midship section, the third.

It was during the voyage of the stern portion, which had been fitted with a temporary bulkhead, from Calais Harbour to Grays, that the disaster occurred whereby Mr. Standfield met his death. Calais was left on Saturday evening for London, the tug *Challenger* towing. About 5 o'clock on Sunday morning a gale and snowstorm set in. Shortly after this, when off the North Foreland, the tow rope broke, and all efforts to get another on board failed on account of the rough sea. During those efforts the *Challenger* struck the lifeboat, and smashed it. The *Ville de Calais* then became unmanageable, and it was tried to head her in shore with the intention of beaching her, but before this could be done, she filled with water and foundered. She probably filled through a leak. In trying to lower the second boat, the tackle broke, and about ten of the

occupants were precipitated into the water. Mr. Standfield was drowned, together with four of the crew. The body of Mr. Standfield was recovered off Deal on Monday morning. The deceased has been engaged in important professional work, commencing with the Grand Trunk Railway of Canada in 1856. In 1857–60 he was engaged in the construction of Victoria Bridge, Montreal, and in 1862–64 of Blackfriars Railway Bridge. In 1864–66 he superintended the widening of Victoria Railway Bridge, Pimlico. From 1868 to 1873 he was resident engineer in sole charge of the erection of the Bombay Hydraulic Graving Dock. In 1874 he entered into partnership with Mr. Latimer Clark, and with Mr. Clark has been largely identified with the progress of hydraulic docks. They designed and constructed depositing docks at Nicolaieff, Barrow-in-Furness, and Vladivostok, as well as large hydraulic canal lifts for the French and Belgian Governments at Les Fontinettes and La Louvière respectively.

Henry Palfrey Stephenson, M. Inst. C.E. (*Past President*), died at his residence, near Croydon, on the 30th April, at the age of 64, he having been, during the last eight years, an invalid unable to leave his house. His bodily ailments did not, however, interfere in any way with his mental powers, and he was still frequently visited by the directors and engineers of several of the companies with which he had been connected, for the purpose of consulting him upon points to which his long and varied experience gave the greatest weight.

Mr. Stephenson was born in 1826, at Portobello, near Edinburgh; his father being in the Sixth Dragoon Guards, then stationed at that place. He was educated at a private school; and spent five years (from about 1842 to 1847) at the College of Civil Engineers at Putney, where Mr. Robert King, the Secretary of the Singapore Gas Company, was a contemporary of his. This college (not now in existence) supplied the basis of the Society of Engineers, of which Mr. Stephenson might aptly be termed "the father," he having been one of its founders and the President as early as 1856, and again in 1859. After leaving the Putney College, he was engaged on the Irish railways, and subsequently (about the year 1849) he was employed at the Sunderland Docks, under the engineer, the late Mr. John Murray, C.E. He then devoted himself to private practice; and one of his first pupils was Mr. Charles Gandon, Engineer of the Crystal Palace District Gas Company. It is interesting to note, in passing, how during the three decades which have elapsed, the business lives of these two gentlemen have continued to mingle.

From the foregoing, it will have been gathered that Mr. Stephenson's training essentially fitted him for a dock and railway engineer; and it was in this capacity that he entered into private business. Among other work which occupied his attention about this time was the designing (in conjunction with his old fellow-collegian, Mr. Robert King) of several iron bridges for Singapore and other places. It was in the fifties that Mr. Stephenson drifted into the gas profession. With that clear perspicacity which marked his whole career, he saw that the then rising gas industry would, before the lapse of many years, assume vast proportions, and that his time and money could be usefully and profitably spent and invested in connection therewith. With Mr. Gandon as his assistant, in 1858 and 1859 he constructed, among other gasworks, those at Naumburg, Ludwigsburg, Zeitz, and Tilsit, in Germany; and the certificates which he obtained from the ruling authorities or companies in those towns—showing that the works were well and substantially built—have been carefully preserved by him, and will continue to be preserved with no less care by the family.

A large number of gas companies have materially benefitted by having Mr. Stephenson either as a Director or Consulting Engineer; and perhaps no man living can lay claim to having served in the former capacity to the extent Mr. Stephenson has done. He was, previous to his retirement, a member of the Boards of the Bahia, Bombay, Singapore, Georgetown, Cagliari, and Pará Gas Companies; and until the day of his death, of the Crystal Palace District and Croydon Companies. He was connected with the Singapore Gas Company from its origination; and was the head of the Board from 1862 to 1882, to which position, on his resignation, the present Chairman (Mr. R. S. Foreman) succeeded. With regard to the Crystal Palace Gas Company, he was associated with Sir Erasmus Wilson and other gentlemen in its promotion, and for many years was the Chairman of the Company, the last time he appeared in that *rôle* being at the half-yearly meeting of the Shareholders on March 23, 1888. Mr. Stephenson was appointed a Director of the Croydon Commercial Gas and Coke Company in 1879. As recently as February 19 last he retired from the office by rotation; and although it was announced that he could seldom attend the Board meetings, the shareholders showed the measure of confidence they reposed in him by re-electing him without a single dissentient. The deep interest which he took in gas matters up to the day of his death is evidenced by the fact that, whenever it was possible for him to

be wheeled out in his bath-chair, he invariably desired to be first taken round the works of this Company, which are situated only a short distance from his house.

Edward Gregson Banner (*Member*) died at Lee, Kent, on the 29th September, at the age of 77. He was born at Horton, in Northumberland, and, although always interested in scientific pursuits, it was not until 1872 that he turned his attention to sanitary science, and applied his energies to the improvement of the then existing sanitary appliances. After numerous experiments and patenting various ideas in connection with sewer-gas excluders, he came to the conclusion that the constant ventilation of foul pipes was the only effective method of dealing with the question, and of preventing the inroad of impure gases into houses. He, with this object, brought out his patent ventilator, which, in conjunction with his arrangement of having an air inlet on the house side of the trap, attracted much attention at the meeting of the Social Science Congress at Brighton in 1875. This system of ventilating drains caused some contention amongst sanitary scientists as to its originality, and was commented on in the Press, but there is no doubt that by his efforts he did a great deal to forward sanitary science.

Charles Hilton Hingeston, Jun. (*Foreign Member*), colonial engineer for the Gambia, West Coast of Africa, died on the 1st October, aged 32, succumbing to an attack of malarial fever, the rainy season having been an unusually unhealthy one, leaving but few of the European officials fit for duty. He had only been residing three months in the colony, having received his appointment in April last. Previous to that he had been engaged in mining operations in Tasmania. He served his articles to Mr. F. L. Duckham, and was afterwards engaged on the works of the London and South-Western Railway, at Stonehouse Pool, Plymouth, where, in gallantly attempting to rescue the crew of a foundering dredger, his boat was swamped and he nearly lost his life.

Ernest Spon (*Member*) died suddenly on the 28th November, aged 41, at Aberdare, where he was staying for the night, previous to an intended visit to a mine in that neighbourhood, for the purpose of carrying out some blasting experiments in the interests of the Smokeless Powder Company, of whose works at Barwick he was the manager. At the inquest the medical evidence showed that death was due to syncope, probably induced by a severe chill.

Although his attention had been principally directed to the

question of explosives, in which he had become an expert, having designed and erected the works at Barwick, and others at Pembrey, South Wales, besides those for the Flameless Explosive Company, at Denaby, near Rotherham, and being constantly engaged in experimenting with a view to the more perfect development of explosive agents, his literary attainments must not be overlooked.

In this direction, the fact of his being a good linguist aided him in gaining access for study to a wide field of technical literature, and to this might be added the further advantage of a literary talent, probably inherited, his relatives having been the founders of the well-known house of E. and F. N. Spon, the technical publishers. He was the editor of "The Dictionary of Engineering," of several colonial engineering publications, and a frequent contributor of articles to other scientific journals, besides being the author of the well-known "Workshop Receipts," and "Modern System of Well-sinking."

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